National Aeronautics and Space Administration




# Reduced Gravity Education Flight Program

## 2010 Annual Report

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# Reduced Gravity Education Flight Program Overview

The Reduced Gravity Education Flight Program provides a unique academic experience for undergraduate students and educators to successfully propose, design, fabricate, fly, and evaluate a reduced gravity experiment of their choice over the course of six months. The overall experience includes scientific research, hands-on experimental design, test operations, and educational/public outreach activities.

## Objectives

- To provide students and educators with an outstanding educational opportunity to explore microgravity.
- To attract outstanding young scholars to careers in math, science, and engineering in general.
- To introduce young scholars to careers with NASA and in the space program in particular.
- To provide a platform for students and educators to understand how microgravity affects research and testing of serious science and engineering ideas.
- To provide an opportunity for both the general public and school children to discover educational and professional opportunities available at NASA.

## Significant Outcomes

- Around 120 college undergraduates from 12 states (representing 13 different institutions) participated in the 2010 traditional undergraduate program. Fourteen proposals were selected for the 2010 flight year. Eleven projects focused on engineering concepts, two were physical science experiments, and one was a life science (including biology) experiment.
- Over 85 college undergraduates and faculty in the System Engineering Educational Discovery (SEED) program from 10 states (representing 13 different institutions) participated in the 2010 program. The projects in this flight week were all system engineering based.
- Over 60 K-12 educators from NASA Explorer Schools (NES), Science, Engineering, Mathematics and Aerospace Academy (SEMAA) and Motivating Undergraduates in Science and Technology (MUST) from 12 states (representing 18 different institutions) participated in the 2010 program. Twenty applications were submitted for the 2010 flight year.
- Over 60 K-12 educators from NASA's Teaching From Space and NSTA Reduced Gravity Flight Week representing 8 states (14 different flight teams) participated in the 2010 program.
- Each selected flight team will also be required to complete a 3-5 minute video of their Reduced Gravity Education Flight Program experience (including how the experiment was selected, hardware build-up, activities in Houston and results). Students have posted several of these videos on YouTube and other various video sites.
- The flight team from the University of Toledo compiled a video segment of the flight experience that aired on WGTE Plugged-In - May 19, 2010. This video will also be broadcast on NASA TV.
- The NASA Explorer Schools (NES) Opportunity flight week brought additional teams representing NASA Science, Engineering, Mathematics and Aerospace Academy (SEMAA) and Motivating Undergraduates in Science and Technology (MUST).
- An additional flight week was developed in conjunction with NASA Teaching from Space (TFS) Office and National Science Teachers Association (NSTA). Also added were two flight teams from the U.S. Department of Energy (DOE) in conjunction with the Princeton Plasma Physics Laboratory (PPPL).
- Several flight teams have submitted papers to present at various STEM-related conferences during the Fall 2010 semester, including the AIAA Conference.

# Program Overviews

## Undergraduate Student Program

The Reduced Gravity Education Flight Program allows teams of undergraduate science and engineering students nationwide to propose, design, and fly a reduced gravity experiment.

The 2010 flights came from all over the United States, with participants from 12 states representing 13 different institutions. Fourteen proposals were selected for the 2010 flight year. Eleven projects focused on engineering concepts, two were physical science experiments, and one was a life science (including biology) experiment.

Overall, all 14 selected teams were able to complete their projects for flight. This included the first teams from the San Jacinto College – North Campus, Embry-Riddle Aeronautical University – Precostt, Arizona campus. This year's participants in the NASA Reduced Gravity Education Flight Program Student Program reported to Ellington Field in June. The following pages contain abstracts about each project. Full final reports are available upon request.

To date, student teams from 49 states have flown. These include 2,920 undergraduate students from 180 universities.

## Systems Engineering Education Discovery (SEED)

The Education Office offered a nationwide solicitation of student applications aimed at addressing systems engineering challenges within both microgravity and lunar gravity environments. Unlike the traditional reduced gravity flight program where students propose the research to be carried out, the NASA technical workforce identified ongoing projects that are systems engineering and reduced gravity related. Selected student groups were then paired with NASA research projects under the leadership of a NASA Principle Investigator to carry out scientific research, hands-on investigational design, test operations, and educational/public outreach activities.

In addition to student involvement, one university/college faculty member was invited to fly with each team. This helped to provide faculty members with teaching materials in their classroom and is used as a motivator to increase their students' interest in systems engineering.

The 2010 flights came from all over the United States, with participants from 10 states representing 13 different institutions. Twenty-three projects were submitted from NASA Johnson Space Center, Ames Research Center, Glenn Research Center, Jet Propulsion Laboratory, Kennedy Space Center, Marshall Space Flight Center, and White Sands Test Facility. Fourteen proposals were selected for the 2010 flight year. Overall, 13 of the 14 selected teams were able to complete their projects for flight. This year's participants in the SEED Program reported to Ellington Field in April. The following pages contain abstracts about each project. Full final reports are available upon request.

## NASA Explorer Schools (NES), Science, Engineering, Mathematics and Aerospace Academy (SEMAA) and Motivating Undergraduates in Science and Technology (MUST)

This "pipeline" strategic initiative promotes and supports the incorporation of NASA content and programs into science, technology, and mathematics curricula in classroom grades 4th through 9th grade classrooms across the United States. Targeting underserved populations in diverse geographic locations, NASA Explorer Schools will bring together educators, administrators, students and families in sustained involvement with NASA's education programs.

Teams composed of full-time teachers and a school administrator develop and implement a three-year action plan to address local challenges in science, technology, and mathematics education. This customized professional development plan will be available based on needs assessments and delivered through on-site school services and via distance-learning networks. The Reduced Gravity Flight Program is one of the special opportunities offered to NES teams.

The NES RGO has been extended to the NASA Science, Engineering, Mathematics and Aerospace Academy (SEMAA) and Motivating Undergraduates in Science and Technology (MUST). SEMAA utilizes a series of unique hands-on, inquiry-based classroom curriculum enhancement activities. The MUST program awards scholarships and internships to undergraduates pursuing degrees in science, technology, engineering and mathematics.

The 2010 flights came from all over the United States, with participants from 9 states representing 10 different institutions. Eighteen applications were submitted to NASA Johnson Space Center. Ten applications were selected for the 2009 flight year. Overall, the 10 selected teams were able to complete their projects for flight. This year's participants in the NES Program reported to Ellington Field in February. The following pages contain abstracts about each project. Full final reports are available upon request.

## NASA's Teaching From Space and NSTA Reduced Gravity Flight Week

Teaching From Space (TFS), located in the Astronaut Office at Johnson Space Center, manages Education

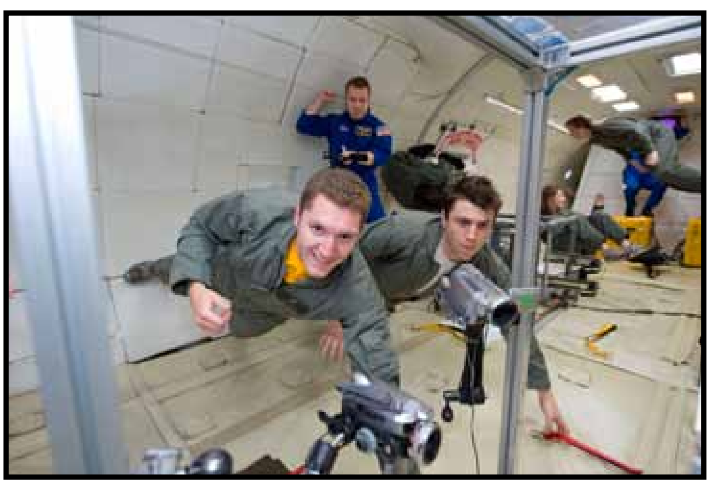
Flight Projects, a NASA Office of Education Elementary and Secondary project. TFS activities are national in scope and involve formal and informal education communities and other NASA Education projects.

TFS facilitates education activities that primarily involve K-12 educators and students. These educational opportunities are designed to inspire, engage, and educate educators and students in science, technology, engineering, and mathematics (STEM) disciplines using NASA unique content and resources. TFS provides K-12 educators and students with instructional and learning experiences that utilize NASA missions, content, people, and facilities. These experiences include educator professional development opportunities and hands on student activities that connect them real time to the Agency's mission and future space exploration.

This flight week is being offered through a partnership between Teaching From Space, the National Science Teachers Association (NSTA) and the Reduced Gravity Flight Opportunities Program. This flight opportunity will allow high school teachers and students to propose, design, fabricate, fly and evaluate an experiment in a reduced gravity environment. Teachers and students will share their experiences and research in a series of interactive Web Seminars after the flight week.

The 12 teams selected for this opportunity, representing 8 states from across the United States, are scheduled to report to Ellington Field in July. The following pages contain abstracts about each project. Full final reports are available upon request.

# Abstracts

**Top, left:** Students experiencing hypoxia as a part of the Hypobaric Chamber Training. **Middle, left:** Educators from Dr. Albert Einstein Academy presenting to the Test Readiness Review Committee. **Bottom, left:** Students from University of Colorado at Boulder taking data from their team's experiement. **Top, right:** A student from Boise State University enjoying the microgravity environment. **Middle, right:** Educators from Bear Creek Middle School taking data from their student's experiement. **Bottom, right:** Juan Moran, a staff member for the Hypobaric Chamber Training, is fitting a student with oxygen equipment as a part of their chamber training.

# Undergraduate Student Program Participating Universities – By State

* First Time Participant (institution)

| State | Institution | Page | State | Institution | Page |
|---|---|---|---|---|---|
| AZ | Embry-Riddle Aeronautical University* | 7 | TX | Austin Community College | 6 |
| CT | Yale University | 11 | TX | San Jacinto College, North Campus* | 8 |
| FL | Embry-Riddle Aeronautical University | 7 | UT | Utah State University | 10 |
| IN | Purdue University | 8 | WA | University of Washington | 9 |
| MI | University of Michigan | 9 | WI | University of Wisconsin at Madison | 10 |
| NJ | The College of New Jersey | 6 | WV | West Virginia University | 10 |
| NY | State University of New York at Buffalo | 8 | | | |

## Austin Community College: Austin, Texas

SRED - Smart Resistive Exercise Device For Free Weight Simulation In Microgravity
Proposal ID: 2010-2485

We propose to construct and test a new type of resistive exercise device which is designed to recreate, in a microgravity environment, both the resistance ( i.e., the "weight") and the inertial properties of free weights. The device is based on a cylinder and piston arrangement whereby one side of the piston is maintained at ambient cabin pressure, while the pressure of the partial vacuum on the other side of the piston is continually re-adjusted by computerized feedback and control to mimic in all details the behavior of arbitrarily selected free weights in a normal gravitational setting. This device addresses the long standing and significant problem of muscle atrophy and bone deterioration due to lack of normal gravitational loading in space flight. The feedback and control algorithm takes input from sensors measuring pressure, acceleration, direction of motion, and applied force and calculates the pressure in the partial vacuum side of the cylinder required to produce the required simulated weight and inertial properties. Digital outputs based on the result of these calculations control solenoid valves which act to adjust the pressure in the cylinder to the targeted value.

## The College of New Jersey: Trenton, New Jersey

Analysis of Dust Particle Dynamics in a Varying Gravitational Field Part III
Proposal ID: 2010-2486

While dusty plasmas are commonly found amongst astrophysical observations and within ground based fusion reactors and other devises, there is a relatively small amount of understanding regarding the dynamics and formation of the dust clouds themselves. There is a great amount of interest in the effects of these dusty plasmas on ground based research, creating the need to better understand the dynamics of the dusty plasma and how to manipulate and control its motion. The field is advancing rapidly, and in an effort to explain the properties of the dusty plasmas, many devices are being brought into microgravity, where results can be obtained that cannot be recreated within the laboratory. The team Dusty Plasma Experiment will test the dynamics of a silica dust suspended in an argon DC-glow discharge plasma. The goal of bringing this research into microgravity is to analyze the dynamics of both the dust particles and the dust cloud itself as a function of varying gravity. The hope is that by eliminating the major force of gravity, we will be able to observe the effects of smaller forces on the dust particles, such as drag. Furthermore, most experiments with dusty plasmas in microgravity have been performed using an RF plasma, so less is known about the dynamics and properties of a DC-glow discharge plasma in microgravity. Previous work on the 'Weightless Wonder' produced very successful, significant results. However, not all of our goals were reached, and our experience has allowed for major adjustments in the experimental set up and procedure, fine tuning the experiment itself and the data acquisition methods. By adjusting the experiment, the Dusty Plasma Experiment III should be able to obtain data in microgravity which will lead to an understanding of the dust cloud formation and dynamics.

## Embry-Riddle Aeronautical University: Daytona Beach, Florida

Project HORIZONS (Harmonic Oscillations Resulting in Zero-G On-axis Nutation of Spacecraft)
Proposal ID: 2010-2493

*Students from ERAU monitor their experiment in parabolic flight.*

The dynamic motion of liquid propellant and its interaction with the solid-body of the spacecraft is of paramount concern. When considering the attitude stability of the oscillating spacecraft as a whole, the sloshing movement of the liquid propellant produces a rotational instability about the vehicle's spin axis, which could potentially lead to fatal consequences for the mission. One such fuel slosh anomaly occurred with NASA's robotic space probe named NEAR Shoemaker. In December 1998, the first attempt of placing the satellite into orbit failed on the first of four rendezvous burns. Right after the burn sequence was initiated, it was immediately aborted which sent the satellite into a "tumble", causing it to lose its solar orientation and battery power. More recently, another such instance occurred with the second launch of SpaceX's Falcon I rocket. Just after launch in March of 2007, the first stage of the rocket successfully completed its burn, however, an abrupt transition to its second stage excited the liquid propellant causing fuel slosh. This disturbance lead to rapid oscillatory nutation growth which caused the rocket to lose functionality. The sloshing caused the rocket to roll, depriving the second stage of fuel and resulting in the failure of the mission. It is therefore important to understand the nature of fuel slosh and how exactly the liquid propellant behaves in order to combat these adverse outcomes. Viscosity effects, brought about by the flow of the liquid propellant, cause the energy of the spacecraft to be converted from rotational kinetic energy to molecular kinetic energy. Since the forces and torques associated with the viscous effects are internal, there is no net effect on the angular momentum of the vehicle; there is only a change in its rotational kinetic energy. This energy dissipation, on a molecular level, will cause the spacecraft to transition about its minor axis (spin axis) to its major axis, producing an unsteady, oscillatory spin. This non-linear, time-dependant nature of fuel slosh has led to some interesting concepts to lessen the effects of the motion of liquid propellant. At the forefront of these concepts is the application of a PMD, or a Propellant Management Device, which is anything installed within the walls of the fuel tank that directly interacts with the liquid propellant. A common PMD is a diaphragm, an elastometric material installed on the inside of a fuel tank. As the liquid propellant is expended, the diaphragm will compress inside the tank to minimize the free surface area inside of the tank directly in contact with the remaining fuel. This will lessen the ability of the fuel to retain a sufficient amount of kinetic energy with which to dissipate through the fuel tank side-walls. However, should the tank be constructed without a diaphragm (a bare tank), the dissipation of the kinetic energy impacts the system directly. As of late, a new phenomenon has arisen for a scenario involving a bare fuel tank filled to 100% capacity. In this anomaly, with the inertia ratio of the spacecraft at 0.9, there is a phenomenon that occurs within the bare tank. NASA's Launch Services Program asked Project HORIZONS to investigate this occurrence and report its findings to gain new insight. Therefore, Project HORIZONS proposes to conduct an additional experiment in the microgravity environment involving a bare fuel tank filled to 100% capacity with a 0.9 effective inertia ratio. The results of this experiment will be analyzed to determine the cause of this phenomenon in order to dampen its effects.

## Embry-Riddle Aeronautical University: Prescott, Arizona

Preliminary Research for Inertia Matrix Estimation (PRIME) Satellite
Proposal ID: 2010-2508

Attitude determination and control systems are very dependent on an accurate estimation of the mass moment of inertia matrix of the satellite. These values can change due to fuel consumption, fuel slosh, docking with other spacecraft, scientific experiments, debris collection, orbital maneuvering vehicle procedures, as well as a host of other factors. Missions that require very fine attitude control and docking procedures can be adversely affected by large changes in system mass properties. PRIME Sat (Primary Research for Inertia Matrix Estimator Satellite) has been developed as an experiment designed to dynamically determine the mass moment of inertia matrix of a satellite to demonstrate a system capable of overcoming the problem of in-orbit changes to inertia. Utilizing the Reduced Gravity Student Flight Opportunities Program (RGSFOP), the PRIME Sat team will test a micro-satellite's ability to determine its mass moment of inertia matrix. While in microgravity, PRIME Sat will use a reaction wheel to apply a known torque about a single axis. PRIME Sat will measure the resulting angular rates and determine how the system is propagating. All data measured onboard the PRIME Sat will be transferred to a ground station for storage and processing. The data will be used in an attempt to estimate an accurate mass moment of inertia matrix for the satellite, and the results will be compared to Computer Aided Design (CAD) models of the system. Microgravity and a free-float environment are extremely important to this mission. First, any tie-down method would introduce forces that the team would be unable to measure or incorporate into the models and equations for mass moment of inertia matrix determination. Second, any apparatus designed to test the satellite in gravity (e.g. an air bearing) would introduce numerous torques on the satellite as well as restrict the freedom of movement so that there would not truly be a full three degrees of freedom. PRIME Sat must be free to rotate 360 degrees about all 3 axes or the system will be unable to determine the products of inertia because of the dependence on measuring the coupled rotational motion. This research has the potential to further develop understanding of in-orbit inertia estimation.

## Purdue University: West Lafayette, Indiana

Effect of Textured Surfaces on Bubble Detachment and Contact Area in Microgravity
Proposal ID: 2010-2481

Flow boiling heat transfer is characterized by high heat transfer rates and minimal mass and volume requirements. Introducing flow boiling heat transfer into a microgravity environment has important applications in both spaceflight and Earth-bound systems. Flow boiling systems can be incorporated into spacecraft design to reduce the size and mass of satellites and vehicles, and can also provide the high heat transfer rates required to maintain the temperature of structures in space. In 1-g, flow boiling is used in miniature flow loops to cool high-powered electronics. In such small-scale cases, capillary forces are largely dominant over buoyancy forces, and the microgravity environment can be used to model system behavior. Research by others has shown that heat flux is a maximum near the contact line. Thus, several research groups around the world are currently focused on developing textured heat transfer surfaces to optimize flow boiling, either by encouraging bubble detachment or by increasing bubble contact line length. By introducing textured heat transfer surfaces into flow boiling systems, heat transfer in microgravity and 1-g can be further improved. The proposed experiment will use a flow boiling model to examine the bubble removal and the growth of bubble contact line on several of these important new textured heat transfer surfaces in microgravity. Bubble diameter at detachment and the length of the bubble contact line will be measured for each surface. As textured heat transfer surfaces are relatively new developments for 1-g flow boiling, the proposed experiment would be the first to explore the behavior of each surface in weightlessness.

*Students from SJCN monitor their experiement in parabolic flight.*

## San Jacinto College, North Campus: Houston, Texas

Further Evaluation of the Effects of Short Term Reduced Gravity on Prothrombin Time of Plasma
Proposal ID: 2010-2481

Understanding how blood coagulates is important, especially in a modified environment such as microgravity. Astronauts must know what changes their vitals will undergo while in space during intricate missions, so procedures can be developed to prevent and manage accidents. The effect of microgravity on blood coagulation has been experimented indirectly by studies that examined aspects of coagulation such as plasmin degradation and assembly of fibrin clots, but more extensive research on the matter is needed to elucidate on factors that may contribute to clot time variances in reduced gravity (1, 9, 14). To date, no biochemical clotting studies have been conducted in flight (Attachment 3.0). Human knowledge of microgravity's effect on the rate of blood clotting is crucial to astronaut safety during missions. Tests have been done using animal blood, but animal and human blood differ, and this difference, no matter how small, will lead to inadequate precaution should an astronaut be wounded in space (22, 23, 24). We know that many of the body systems slow down, organs don't secrete as much as they normally do, and cell production is decreased, which leads us to believe blood coagulation is slowed while at reduced gravity (24). To test this hypothesis, out team plans to use human control plasma and an enzymatic blood-clotting test, the Prothrombin Time (PT) test accomplished through the Abbott ISTST analyzer already used by NASA and the air force for fluid analysis, while in flight on the C-9. This study will also be replicated on ground. As we are conducting a re-flight, we expect our data to confirm the decreased clotting activity that was suggested in 2006 (Attachment 10.0) by removing variables that compromised the experimental validity of previous student research.

## State University of New York at Buffalo: Buffalo, New York

Relative Attitude Determination for Satellite Formation Flying
Proposal ID: 2010-2484

Formation flying in satellites is a field of high interest in the aerospace industry. Formation flying requires a high amount of accuracy between spacecraft; the proposed method investigates concepts in relative spacecraft navigation using a formation of two satellites and a third arbitrary point. This will be performed by utilizing information provided by the visual navigation system. Using these sensors, an algorithm can be used to compare each spacecraft's relative orientation to each other. Using a third point, each spacecraft will be able to determine its relative rotational orientation.

## University of Michigan: Ann Arbor, Michigan

Exploring the Design Space of the Dry Configuration of the Nanoparticle Field Extraction Thruster in Microgravity
Proposal ID: 2010-2492

The Nanoparticle Field Extraction Thruster (NanoFET) is a novel electric propulsion device under development at the University of Michigan. The NanoFET system uses micro/nano-electromechanical systems (MEMS/NEMS) to electrostatically charge and accelerate micro/nano-particles and create thrust for small satellite applications. With NanoFET, the goal is to create a single electric propulsion device that is easily throttle-able to host a large range of propulsive tasks. ZESTT Reflight proposes to fly a NanoFET prototype to determine its performance in microgravity. Team ZESTT Reflight will take the lessons learned from the 2009 ZESTT campaign1 (M-1 prototype) and apply them to design, build, test, and fly a second generation (M-2 prototype) of NanoFET. The team will design a feedback controlled piezoelectric (piezo) based feed system to disperse particles through a charging micro-sieve. An induction charge detector (ICD) and Faraday probe are also being designed to evaluate NanoFET's performance in near space conditions – i.e., under vacuum and in microgravity. It is required that the ICD and Faraday probe have nano-Amp precision and accuracy to adequately measure the current induced by charged particles. Prior to flight, extensive ground testing will be conducted to confirm expected operation of the diagnostic tools that will be used. A baseline data set will be gathered from the M-1 thruster. Ground testing of the M-2 will also begin to characterize its performance with respect to applied electric fields, piezo actuation, and particle mass density. Microgravity tests will be used to validate ground test results as well as NanoFET theoretical models to develop the design drivers of future NanoFET generations.

## University of Michigan:  Ann Arbor, Michigan

Evaluating the Extendable Solar Array System in a Microgravity Environment
Proposal ID: 2010-2505

The eXtendable Solar Array System (XSAS) is a modular satellite power generation system under development at the University of Michigan for use on CubeSats (a type of nanosatellite design that has been standardized by California Polytechnic State University). When fully deployed in orbit XSAS has the potential to supply up to 5-7 times more power than current CubeSat capabilities with the help of its solar panel extension of nearly 7 feet. This extension can also act as a boom to facilitate a gravity gradient stabilization system. With its modular packaging, XSAS can be easily integrated into a variety of different CubeSat missions. Our goal is to examine the deployment of the XSAS system in various tumbling conditions through a largely automated experiment. Our project will focus on the structural mechanics of XSAS and the deployment dynamics in microgravity. Our experimental variables are the ballast masses, hinge springs, latching mechanisms, and rotation rates during deployment. The rotation rates will correspond to off-design scenarios where the satellite has not fully de-tumbled in orbit before deployment. To simulate the conditions of deployment in orbit, a microgravity environment is necessary to allow the required six degrees of freedom associated with translation and rotation. We will analyze the deployment using data obtained from accelerometers, strain gauges, and cameras. This data will allow us to determine the forces, moments, and deflections on XSAS. The data that we obtain from our flight tests will be used to suggest improvements to the XSAS design and increase the Technology Readiness Level. The knowledge and data that we gain will also allow us to complete a lessons learned document for future free-float microgravity testing projects.

## University of Washington:  Seattle, Washington

Rotational Damping of Slosh in Microgravity
Proposal ID: 2010-2472

From Apollo 11 to NEAR, fluid sloshing within partially filled propellant tanks has plagued countless space missions. One solution is a rotating fluid tank which uses centripetal acceleration to force liquids to the outside of the container and maintain a stable gas column in the center. Consequently, this results in a predictable center of gravity of the tank and the contained liquid. In 2006, however, SpaceX lost a Falcon 1 rocket to a case of rotational forces gone awry. As the rocket's first stage detached, there was an impact between the interstage and the second stage, inducing oscillations and a small rotation of the second stage. As the propellants drained, the angular velocity of the rocket increased due to conservation of angular momentum. It began to spin so fast that the propellants could not be extracted, thereby halting thrust and rendering the vehicle unable to reach its orbit. Clearly, merely rotating a propellant tank is insufficient. Inspired by this failure, University of Washington students have designed the Rotational Damping of Slosh in Microgravity mechanism, RDSM, which consists of a tapered tank, having a larger diameter at its base than at its top. This design provides a consistent centripetal acceleration which both stabilizes the liquid's center of gravity and draws the fluid toward a common collection point for extraction. Currently, propellant tanks utilize ring baffles to attenuate slosh disturbances. With a tapered rotating design, standard ring baffles would defeat the purpose of the tapering; therefore, the ring baffles will be replaced by a corkscrew shape to provide additional damping capabilities whilst drawing fluid to the base of the tank. Since there is only a specific amount of power available in a spacecraft, and angular velocity is a monotonic function of power, it is the goal of this experiment to confirm the effectiveness of the RDSM design in mitigating fluid slosh, and to determine the minimum amount of rotation necessary to create a reasonable amount of slosh damping.

## University of Wisconsin at Madison: Madison, Wisconsin

The Influence of Frequency on the Performance of Ultrasonic Enhancement of Liquid Convection Cooling in Variable Gravity
Proposal ID: 2010-2503

Ultrasonic liquid cooling has been shown to be an effective method for cooling surfaces in a variety of applications on Earth. By tracking changes in the heat transfer coefficient, this experiment will determine how gravity affects ultrasonic cooling. In addition, this experiment will investigate how changing the ultrasonic frequency can mitigate any possible changes that gravity causes. Results from this experiment will help determine the usefulness of ultrasonic liquid cooling in space applications as an efficient alternative to current cooling methods.

## Utah State University: Logan, Utah

FUNBOE Follow-Up Nucleate Boiling On-flight Experiment
Proposal ID: 2010-2501

*Students from Utah State monitor their experiement in parabolic flight.*

As humans explore further into space, thermal management systems will require greater robustness, efficiency, and reliability. Nucleate boiling is a well-known and heavily researched mode of boiling and would be ideal for thermal management systems due to its associated high heat transfer rates. However, nucleate boiling dynamics in microgravity are not well understood due to the fact that previous experiments have produced contradictory results. Without buoyancy as the dominant force, the fluid dynamics are heavily dependent on system characteristics such as working fluid, degrees of subcooling, heat flux, and surface geometry; therefore, the resulting dynamics of one system cannot readily be used to determine the dynamics of another. The proposed study follows up on a previous experiment flown onboard Space Shuttle Endeavor (STS-108) as part of the Utah State University (USU) Get Away Special (GAS) team's previous outreach efforts motivated by the former NASA GAS Program. After student analysis of the initial nucleate boiling experiment developed by Box Elder High School and the GAS team, it was determined that a follow-up experiment was needed that incorporates better thermal monitoring and higher resolution video recording (Koeln, 2009). This was absent from the previous experiment. Following the previous outreach pattern, FUNBOE is meant to involve K-12 students and GAS team members from a variety of disciplines in studying the effects of system characteristics on nucleate boiling behavior in microgravity. Multiple fluid chambers incorporating different heating element geometries and power inputs (resulting in different heat fluxes) will determine which system characteristics correlate to improved heat transfer. Experiments performed in microgravity and on earth will be compared to determine if nucleate boiling is an effective means of heat transfer in microgravity. Increased understanding of system characteristics of nucleate boiling, like heat flux and surface geometry, will allow accurate models to be developed.

## West Virginia University: Morgantown, West Virginia

Controlling Fuel Sloshing Through the Use of a Ferromagnetic Solvent Manipulated via an Electromagnetic Field
Proposal ID: 2010-2486

Propellant sloshing in microgravity occurs when a force is applied to a fuel container during launch, maneuvering, or docking. The resulting sloshing motion of the liquid can alter the trajectory of the spacecraft which may cause mission delays or failure. These effects are amplified in microgravity because the fluid sloshing is prolonged due to the lack of gravitational forces. Therefore, controlling this fluid sloshing behavior is essential for accurate spacecraft navigation. The proposed experiment studies the feasibility of controlling sloshing in microgravity using a ferromagnetic fluid (ferrofluid) and an electromagnetic field. The magnetic field effects induced on the ferrofluid emulate an effective body force as a substitute for the lacking gravitational force that will help to confine the fluid, alter any sloshing frequencies, and provide damping of such a system. The use of a magnetic field is expected to help confine the ferrofluid in its desired position and to increase damping of any resulting sloshing motion under microgravity conditions. The ferrofluid EFH1, commercially manufactured by Ferrotec Inc., is currently being considered for use in testing due to the availability of literature identifying its fluid properties. A stepper motor, connected to one cylindrical and one two-dimensional test tank by linkages, will induce sloshing by setting the tanks into oscillatory motion. Once significant sloshing is apparent, the motor will be stopped and the resulting effect of the magnetic field on the ferrofluid will be recorded. Fluid level measurements of the liquid free surface will be correlated to the sloshing motion. Various methods of data collection will be used to gather both quantitative and qualitative data. The data collected will be used to analyze the effects of the electromagnetic field upon the ferrofluids sloshing behavior under microgravity conditions.

## Yale University: New Haven, Connecticut

Crystalline Structure Transformation in Complex Plasma
Proposal ID: 2010-2509

The study of dusty plasma is of central importance to NASA's space science strategic enterprise, especially with regard to planetary accretion and the improvement of industrial depositional processes. Since the discovery of the crystalline structure of complex plasma in 1994, the dynamics of these complicated systems have been the focus of myriad experiments conducted on Earth, aboard the ISS, and on parabolic flight campaigns. The goal of this experiment is to image dusty plasma microgravity crystalline structure and its transformation during the continuously changing gravitational conditions of parabolic flight. A dual-camera, dual-laser system on motorized translation stages will allow the collection of images that can be analyzed using particle-tracking algorithms to determine particle spacing and Debye lengths as a function of gravitational force. This follow-up experiment incorporates vastly more reliable and easily maneuverable imaging equipment, a redesigned vacuum chamber with a stronger plasma sheath and thus a larger cloud-forming area, and the opportunity to measure plasma parameters using a Langmuir probe on the ground as well as to characterize system responses to microgravity in a drop tower facility. Our outreach activities have matured, becoming more integrated in school curricula (FIRST Robotics program) and aiming to encourage the pursuit of "outside-the-classroom" science applications.

# SEED Undergraduate Students
# Participating Universities – By State

* First Time Participant (institution)

| State | Institution | Page | State | Institution | Page |
|---|---|---|---|---|---|
| CO | University of Colorado at Boulder | 15 | MO | Washington University in Saint Louis | 19 |
| CT | Yale University | 19 | NE | University of Nebraska at Lincoln | 17 |
| ID | Boise State University | 12, 13 | OH | Ohio State University | 14 |
| IN | Purdue University | 15 | OH | University of Toledo | 18 |
| KY | University of Kentucky | 16 | WI | Carthage College | 13 |
| MA | Massachusetts Institute of Technology | 14 | WI | University of Wisconsin at Madison | 18 |

## Boise State University: Boise, Idaho

Measuring the Dielectric Properties of Lunar Regolith to Detect Water and Other Compounds
Gravity Type: Lunar

Lunar regolith contains some unique electrical and chemical properties. Several lunar simulants exist that mimic these properties. On the Moon, the dust layer has a different packing density compared to that on Earth because the pull of gravity is 1/6 that of Earth. One method for characterizing the components in regolith such as iron or even water is through complex impedance measurement. An instrument has been developed to analyze the impedance of soils. Various lunar simulants should be tested on the ground and in 1/6g. The flight rig should allow the operator to safely test the various simulants using the impedance analyzer, record test results and maintain proper simulant containment on board the aircraft. This data will contribute to research in the advancement of instruments used for future NASA missions to the Moon.

Large projects demand a breakdown of subsystem level components such as safety, electrical interfaces, mechanical structures and science objectives. This project will require that the system schedule and budget are followed given the time constraints, the impedance-measuring instrument is integrated with a flight rig and the experiment is built to meet the flight requirements. This project has several multi-disciplinary requirements. Electrical engineers understand data acquisition, electric fields and dielectric properties. Mechanical engineers understand structures and the factors of safety required for constructing a successful flight rig. Materials science engineers have an understanding of complex materials such as regolith and its molecular, mechanical and electric properties. Most important is that the system engineer must understand how any one of these components affects each other and the project as a whole. The schedule and budget must be followed to meet the phases of the project lifecycle from concept to flight.

NASA's future of human space exploration lies in the success of the Constellation program. The return to the Moon and Mars will help us learn how to live and work on another planet. Water is a key component for life and a crucial element in the sustainability of a lunar habitat. The Lunar Reconnaissance Orbiter is a current mission that is exploring the possibility of ice water at the poles of the Moon. Water or other useful compounds may exist in the regolith layer on the Moon. By measuring the properties of regolith in a lunar gravity environment researchers can create more precise, localized instruments to detect water and other compounds in the soil.

NASA Technical Contact: Dan Isla – Jet Propulsion Laboratory

## Boise State University: Boise, Idaho

Dynamic Wheel Traction Concepts in Lunar Gravity
Gravity Type: Lunar

*Students from Boise State University monitor their experiment in parabolic flight.*

As humans prepare to return to the Moon and Mars, new transportation systems are required to deal with the reduced gravity and unique regolith terrain present on both of these surfaces. Gravity plays an important role in native soil properties (especially shear strength), and hence, vehicle traction. Atmospheric pressure (on earth) or vacuum in case of other planets, also have strong effects. An understanding of how the wheel-surface of these vehicles interacts with these environments is important for future exploration/habitation efforts. The previous year effort for this project had focused on the torque required to overcome static friction. An important concept in addition to a wheel's static response is its dynamic response under acceleration and constant speed motion. In a continuation of previous years' analysis of the static response of a wheel in lunar gravity, this project focuses on the wheel dynamic response. Students can explore the relationships of lunar traction concepts of different wheel designs in regards to the following criteria: • Wheel treads • Applied normal load • Torque to overcome static friction • Power to maintain speed and/or accelerate • Slippage vs. traction • Effect of free regolith compaction • Effect of confinement and wheel surface area

This project includes a variety of disciplines, requiring coordination between mechanical, electrical, civil, and materials engineering. The mechanical design of the test apparatus and physical safety systems is important to the success of the project, and must interact with the electrical power systems for motor control and sensors. The behavior of the regolith in both lunar gravity and 1-G is related to the geotechnical discipline of civil engineering, but at lunar conditions. Sturdy and light materials are critical to space exploration, due to the high cost of launching heavy cargos from Earth. Students also need to pay attention to other systems engineering criteria like optimizing cost, schedule, and performance.

Establishing a lunar base on the moon, in preparation for future missions to Mars, requires a vehicle, which astronauts can rely upon, to safely carry cargo and/or persons between distant points efficiently.

NASA Technical Contact: Pedro Curiel – Johnson Space Center

## Carthage College: Kenosha, Wisconsin

Investigation of Propellant Sloshing and Zero Gravity Equilibrium for the Orion Service Module Propellant Tanks
Gravity Type: Micro

The Orion service module contains a liquid biprop propulsion system for orbital maneuvering and trans-Earth injection burns. The fuel and oxidizer are each housed in two tanks connected in series. Propellant management devices (PMD) in each of the downstream tanks provide gas free propellant in zero gravity conditions to the main engine, auxiliary engines, and reaction control system, to ensure adequate system performance is maintained. Due to the large quantity of propellant for this particular spacecraft, understanding liquid slosh during docking, zero-G, low-G, and high-G maneuvers is important for maintaining dynamic control. It is also important to understand how the propellant settles during long duration exposure to microgravity conditions with respect to Orion's specific tank design for propellant mass gauging and center-of-gravity control. In this project the students will be recreating a model of the Orion downstream propellant tank(s) including the internal physical structures of the PMD and mass gauging probe. Since the actual tanks are quite large, accurate scaling of the dynamic forces and the tank itself will be important. Matching of propellant properties to the experimental fluid (surface tension, density, etc.) must be considered as well. The students have the option to develop a test plan and apparatus for imparting and measuring different slosh forces. This includes achieving an accurate acceleration profile of the aircraft such that vibrations and other effects from the plane can be considered when interpreting the results. In this case the experiment would be free floating. However, this may prove to be logistically challenging so it might be beneficial to use the plane as the high-g sloshing force while the tank is attached to the aircraft. The first parabolas for each test set can be used to ascertain the equilibrium position for the fluid in the tank in zero gravity and the time it takes for the fluid to settle in that position. Liquid to tank fill fraction is one of the parametric considerations, so the tank will need a system for accurate draining into a reservoir after each set of experiments is complete. Ultimately, the results from this experiment will be used to both validate and improve analytical models of propellant slosh in the SM tanks.

In this project there are a number of complex systems challenges to overcome. While the majority of the physics will be fluids and aerospace related, the need for good electronic equipment and data acquisition methods is critical. Fluid visualization is very important in this study as well as converting the raw visual data into quantitative information that can be used to adequately address the questions being explored. Accurate flow rates and plane acceleration profiles will also be needed. Students and the project will benefit from forming an interdisciplinary team and assigning tasks appropriately.

The Orion crew exploration vehicle is the next generation spacecraft for human space exploration with Lockheed Martin as the lead contractor. As part of the Constellation Program and Vision for Space Exploration, Orion directly supports NASA's Exploration Systems Mission Directorate by providing the agency with safe and reliable access to the International Space Station and eventually the lunar surface. In both instances, astronauts will be given great opportunity for scientific study in astrophysics, planetary geology, biological sciences, and impacts of long term human exposure to zero gravity conditions, just to name a few.

NASA Technical Contact: Jonathan Braun – Johnson Space Center

## Massachusetts Institute of Technology: Cambridge, Massachusetts

Compaction of Lunar Regolith for Dust Mitigation
Gravity Type: Lunar

Fine dust knocked off the lunar surface during manned and unmanned exploration activities poses a range of hazards to equipment and astronauts. This experimental program will study the effects of compaction of the lunar regolith on the amount of fine particles that are knocked off the surface, and at what speeds. Previous microgravity experiments with JSC-1 lunar regolith simulant showed, serendipitously, that at a relative density of 0.5 or higher the amount of dust knocked off the surface is small. This project will involve samples of lunar regolith simulant in sealed evacuated containers at predetermined relative densities. (Relative densities are a measure of the compaction of a granular material.) The samples will be maintained at the desired relative densities through spring-loaded tops to the sample containers. During lunar-g parabolas, a sample will be exposed and subjected to a series of impacts at increasing energies. High-speed video will capture the amount of dust ejecta produced and enable post-flight measurements of the velocity distribution. The samples will be large enough so that boundary effects of the container do not affect the response of the sample to the impacts (~10 times larger than the impactor). A typical sample container might be a cylindrical box ~20 cm in diameter and 10-20 cm in depth. The samples need to be evacuated because air has a strong lubricating effect on the motion of granular media. Impacts on the surface can be accomplished with a piston mechanism driven by a solenoid, or spring-launched projectiles. Results will be a measure of dust ejecta mass and velocities as a function of impactor energy and regolith relative density.

The architecture of future lunar outposts will have to include a plan to deal with dust contamination. The proposed project will provide data that will help determine if preparing compacted-soil work areas will reduce dust contamination. This would affect the site plan for lunar outposts.

The proposed research addresses the concern of dust contamination of lunar habitats and equipment deployed on the lunar surface. The results will indicate whether, and to what extent, compaction of the lunar regolith reduces the incidental production of dust from the surface by exploration activities. Dust kicked off the surface will adhere to astronauts and equipment and then potentially be transported into living habitats. Preparation of the surrounding lunar surface through compaction of the soil may reduce this hazard. The proposed experiments will quantify this effect, first hinted at by the microgravity experiment Collisions Into Dust Experiment (COLLIDE) performed on the space shuttle to study planet formation.

NASA Technical Contact: Greg Galloway – Kennedy Space Center

## Ohio State University: Columbus, Ohio

Correlation of 1-g Aerospace Materials Flammability Data with Data in Reduced and Microgravity Environments
Gravity Type: Lunar


*Students from Ohio State University monitor their experiement in parabolic flight.*

Correlation of ground 1-g materials qualification flammability tests with microgravity data is of crucial importance to determine if the ground test data is conservative when applied to spacecraft microgravity environments. The current NASA STD 6001 Test 1 data is mostly conducted in 30% oxygen at 10.2 psia, which is considered as the "worst expected" condition in spacecraft from a flammability point of view. Ground data taken under fixed conditions is not amenable to be correlated with microgravity environments; due to lack of information, NASA STD 6016 assumes a one-to-one correlation, which may not be realistic. Determination of real correlations between materials flammability in ground and microgravity environments is important to determine the safety factors involved when selecting aerospace materials. NASA WSTF developed a method to determine the Maximum Oxygen Concentration (MOC) at which a material would self-extinguish; the approach has been used to qualify materials for the Constellation Program. This approach allows quantitative correlations between the 1-g and microgravity flammability data. As part of the SEED Program, during 2009 Ohio State University students built a test system and performed a few tests in lunar-gravity environments using the NASA Microgravity Plane. The results are very encouraging and continuing this work would benefit our Space Program.

Materials flammability is a major spacecraft safety concern. Knowing fire safety factors will lead to decreased possibility of a catastrophic event. Hypoxia, decompression sickness (DCS) prevention during an EVA, and materials flammability are major criteria for selecting the spacecraft environment. Prior to an EVA, the astronauts have to be exposed to enriched oxygen at lower total pressures; oxygen enrichment results in increased materials flammability. Knowing how materials flammability changes with environment changes will allow to take adequate precaution during these operations. In addition, any instance which may result in increased cabin oxygen concentration will allow mitigation by knowing which spacecraft components are most at risk.

Correlation of laboratories test data to real-life conditions is necessary for any materials flammability evaluation method, and is of increased importance for spacecraft applications because of potential steep penalties for incorrect assumptions. The approach and technology development during this project is likely to have broad applicability.

NASA Technical Contact: David Hirsch – White Sands Test Facility

## Purdue University: West Lafayette, Indiana

Characterize the Escape of Water Vapor through a Heated Trash Composite in Reduced Gravity Environments
Gravity Type: Micro

Water removal from trash requires that the water or water vapor pass through a column of mixed trash before leaving the waste processing chamber. The effects of microgravity and reduced gravity environments on this process are not known. The effect on removal or collection rates would be the primary data set of interest for this experiment. The device would typically be a tube or box that is heated on one side and the water vapor is removed opposite the heated side of the container. Another option is to heat all sides of the container (with the exception of the heater opposite to the water vapor removal port) just above the evaporation temperature of the water at the selected process pressure. The heater opposite to the water vapor removal port would be set at a higher temperature than the other heaters in order to provide the driving force for water removal via increased heat transfer through the trash. The purposes of the remaining heaters that are set just above the evaporation temperature are to prevent condensation of the water vapor before leaving the waste chamber. This experiment should be performed at lower chamber pressures in order to reduce the evaporation temperature and prevent melting of any plastic component of the waste. However, working with a pressure chamber would require additional safety protocols and measures so research this approach very carefully. Also of interest would be the effects of these different environments on the heat transfer through the trash although this data is not necessary if acquiring it makes this experiment too complicated. There may be a creative way off gathering this type of data during the short reduced gravity periods but this would take more thought about to achieve this.

In this proposal there is a problem on how best to characterize the escape of water vapor through a heated trash composite. Several investigate approaches are suggested in the project description but the students can also research many other approaches. For buildup of the rig, the students will be testing, modeling and integrating several features to see which works best. From their test on the plane, they will be able to assess the performance of the designs and how well they work. All these are key features of a system engineering process.

This test would be able to provide insight into a way to characterize the escape of water vapor through a heated trash composite. The Waste Management element in Exploration Life Support Program is responsible for the development of technologies and approaches to manage the numerous types of waste materials generated in future human space flight. The results of this project can therefore benefit other hardware development and design efforts.

NASA Technical Contact: Greg Pace – Ames Research Center

## University of Colorado at Boulder: Boulder, Colorado

Personal Body Attached Liquid Liquidator (PBALL)
Gravity Type: Micro

This project involves designing and testing a subscale contingency wastewater disposal system for the CEV. The Personal Body-Attached Liquid Liquidator (PBALL) is conceived to rely on capillary action and urine wetting design strategies. The PBALL must also be designed to accommodate a range of wetting conditions, from ~0o to ~90o ?adv. The PBALL is designed to accommodate both male and female urine streams, collect and retain up to a liter of urine, minimize splash-back, and allow continuous drain of the wastewater to vacuum while minimizing cabin air loss. The accommodation of male and female streams is the key design requirement that distinguishes the PBALL from the Apollo-era urine removal assembly (URA) that relied on a urine jet impacting a honeycomb material. Instead, female urinary streams are less cohesive and spread out, and women prefer to be closer to the funnel. The PBALL is composed of a crew interface, a void volume to retain the bulk liquid, and a capillary fan region that serves to draw the urine away from the void volume and towards the vacuum drain port. The void volume serves to contain the bulk liquid while the crewmember is urinating, such that capillary action is not relied upon to draw the urine away from the body faster than the urination speed. Instead, the top of the capillary fan region simply contains the liquid and minimizes splash. This draws on the experience with the SPS, where it was observed that the capillary pumping velocity was significantly slower than the liquid flow rate. However, the pinning effects of high contact angle interactions can reliably be used to contain the bulk liquid against some opposing force. The capillary fan region utilizes capillary wedge geometry to collect, contain and dispose of the wastewater. The matrix of wedges have a decreasing interior angle that promotes capillary pumping, and perforations that allow cross-talk between the vanes. The inertial force of the wastewater stream serves to penetrate the urine into the wedges, wherein capillary action draw the urine down to the drain port. Draining is obtained in a continuous piece, minimizing air loss, when a valve opens the PBALL to vacuum.

The PBALL unit is a contingency device for the CEV. The requirements to accommodate both male and female urine streams, collect and retain up to a liter of urine, minimize splash-back, and allow continuous drain of the wastewater to vacuum while minimizing cabin air loss all rely on careful integration with other spacecraft systems, including the life support technologies, crew interfaces, and fluid systems. The CEV has proven to be a complex vehicle where resources are tightly managed and functionality may be only zero or one fault tolerant. Contingency devices, such as the proposed PBALL, have to consider all the other systems in the spacecraft, and in particular the crew interaction, in order to minimize resource use and maximize functionality.

Long duration spaceflight, such as Moon and Mars missions, will require hardware that is less prone to fouling and generally more rigorous and sustainable than the current state-of-the-art. One application requiring innovation is wastewater management, wherein wastewater fouling is accommodated by the design of the fluid management hardware. Current technologies for microgravity fluid management utilize either centripetal acceleration or capillary action to separate liquids from gases without the benefit of terrestrial buoyancy. However, centripetal acceleration hardware is prone to failure because of liquid fouling, while capillary-based technologies have only been utilized in known and favorable capillary wetting environments, wherein the capillary advancing contact angle, ?adv, a key design criterion, is reliably low. Instead of attempting to prevent or reduce wastewater fouling, sustainable fluid management systems can be designed to accommodate fouling. A direct application of this concept is the PBALL, wherein it is anticipated that wastewater fouling of the system will result in highly fouled surfaces with small surface defects that have high capillary pumping rate. This is the most likely outcome of wastewater fouling and demonstrates the positive impact of wastewater fouling on capillary pumping influenced systems. Demonstrating the PBALL concept will lend credence to this concept for sustainable exploration-class life support technologies.

NASA Technical Contact: Evan Thomas – Johnson Space Center

## University of Kentucky: Lexington, Kentucky

Bubble Free Injection Syringe
Gravity Type: Micro

A dual plunger syringe was designed for a microgravity fluid physics experiment to separate the gas bubble and then dispense the liquid contents. This design was never tested in reduced gravity. The concept was that the plunger shafts were concentric. The innermost shaft was mounted to a porous plate that was “wetting.” The outer shaft was for the syringe plunger proper. A typical liquid syringe contains not only the liquid, but a gas “ullage” bubble that will cushion liquid volume changes caused by temperature changes that affect the liquid density. It is usually desirable though to only dispense liquid from the syringe at the prescribed moment. This system will remove the gas bubble by forcing it out by depressing the inner plunger and allowing liquid to accumulate behind the porous plate. Afterwards, the outer plunger is depressed to expel the liquid from the syringe. Conceptually, the experiment would consist of a outer containment glovebox, with prepositioned cameras that would image the gas bubble and liquid. Stepper motors would control the plunger depression velocities.

While this project is geared towards testing a hardware concept, the development of the test apparatus requires a systems engineering approach. There are structural and fluid containment requirements to satisfy the aircraft safety and operations constraints. Optics and image recording operations must meet the test objectives of visualizing the bubble and liquid within the syringe and maintaining the fluid containment requirement. The use of a stepper motor will require software control, and electrical wiring for both control and power. The experiment concept is simple; however, the development of the hardware requires several different skills and the ability to tie these skills and subsystems together.

The Human Research Program is evaluating concepts for medical injections into EVA suits in a reduced gravity environment. Typical medical syringes have a gas bubble within the syringe barrel that need to be expelled. In a normal gravity environment, these syringes are typically pointed upwards to use buoyancy to force the gas bubble towards the syringe exit before the syringe barrel is depressed. Other techniques have had marginal success.

NASA Technical Contact: John McQuillen – Glenn Research Center

*Students from University of Nebraska at Lincoln monitor their experiment in parabolic flight.*

## University of Nebraska at Lincoln: Lincoln, Nebraska

Cryocooler Validation for the VASIMR ISS Demonstrator Mission
Gravity Type: Micro

A flight of the Variable Specific Impulse Magnetoplasma Rocket (VASIMR) VF-200 onboard the International Space Station (ISS) is planned for the 2012/2013 time frame. The VF-200 is a high power, 200 kW, plasma rocket prototype that will be used to demonstrate and validate key VASIMR technologies and related plasma exhaust plume physics phenomena in Low Earth Orbit (LEO). The baselined VF-200 design includes a set of High Temperature Superconducting (HTS) magnet assemblies. The low mass and high critical field of the planned HTS assembly will enable the VF-200 and future VASIMR engines to operate at competitive efficiency levels, compared to existing state of the art ion thruster technology, such as the NASA Evolutionary Xenon Thruster (NEXT). The use of cryo-cooler devices is required to keep the HTS magnet assemblies at or below 40 K, 40 degrees above absolute zero, for the duration of the ISS mission. The goal of this proposed microgravity project is to validate the cryo-cooler efficiency levels and cooling capacity reported by the manufacturer in super-gravity,1.8g, and micro-gravity,<0.1g, environments. The VF-200 design will require 10-12 15 W cryo-coolers to sustain the HTS low-temperature environment. The HTS magnet assembly will reside within a cryo-shield, used to block direct solar and Earth-albedo UV, visible, and IR radiation from heating up the HTS magnet and magnet assembly. Several competing cryo-cooler technologies exist, however due to mass, lifetime, and efficiency considerations, the commercially produced SunPower CryoTel line of cryo-coolers is the leading contender for VF-200 HTS operation. The CryoTel cryo-coolers are an off-the-shelf technology commonly used in low temperature medical, sensor, telecommunications, and pharmaceutical applications. In fact, a slightly modified version of cryo-cooler, the M77, from SunPower has been flown on NASA's RHESSI satellite. A slightly newer model, the M87, will also be used onboard the Alpha Magnetic Spectrometer, a particle detector device that will also reside on the ISS in the 2010/2011 time frame. Though the CryoTel line of cryo-cooler is the successor to the M77 and the M87, the CryTel line has never been operated in a microgravity environment. This microgravity demonstration is necessary in order to mitigate risk associated with using this off-the-shelf technology for a spaceflight application such as the planned VF-200 mission to the ISS. The students involved in this particular SEED proposal would be requested to: 1) Construct an acrylic/lexan project box with appropriate electrical and gas/venting feedthroughs. The acrylic/lexan project box should comply with NASA's C-9 safety standards. 2) Assemble a data acquisition system to log pressure and low temperature thermal data throughout the flight. 3) Design of a simple cryo-shield to possibly include Multi-Layer Insulation (MLI) to insulate the cryo-cooler cold heads from the ambient temperature cryo-stat vacuum vessel walls. 4) Identify component and system failure modes of the SEED experiment and mitigate experiment failure probability through design choices and design iteration. We have partnered with SunPower, and there is a partnership in place to support the testing of at least one, but mostly likely 2 or 3 CryoTel cryo-cooler designs. The cryo-coolers will be loaned to us for this testing purpose. A small vacuum vessel will be provided by the proposer (Ad Astra Rocket Company) to insulate the cold head of the cryo-coolers from atmosphere. The vacuum vessel is used to keep the air from condensing out onto the cold head. At the temperature range of interest, ~40 K, nearly all atmospheric gasses solidify into an ice. A vacuum pump will also be provided by the proposer in order to evacuate the vacuum vessel. The proposer will also provide existing in-house vacuum lines and vacuum pressure measurement equipment for the SEED experiment. The PI and the support NASA contractor lab, the Ad Astra Rocket Company, are located in Webster TX, 1.5 miles from the Johnson Space Center and 2 miles from Ellington Field. The students and faculty advisor will be given extensive laboratory tours of the Ad Astra facilities, including a 150 cubic meter space simulation vacuum chamber and the VX-200, a ground prototype of the VF-200 ISS testbed. The potential exists for highly motivated students to be invited to spend an internship at the Ad Astra Rocket Company, further developing the VF-200 cryo-cooler design.

Throughout the course of this project, the students will be expected to be familiar with the full operation of their experiment and all hardware contained within it and data acquisition systems, including pump-down procedures, cool-down procedures, nominal flight procedures, warm-up procedures, and venting procedures. The students will be expected to go through the full spectrum of systems engineering to identify failure modes of each component and the system and experiment as a whole. In identifying these failure modes, the students are expected to make critical system components doubly or triply redundant, identical to actual spacecraft operation and design constraints. It is requested that the students construct a block diagram of each component in the experiment with associated written procedures of the operational tasks and troubleshooting guidelines. The PI has personal microgravity experience and 5 years of microgravity team mentoring experience. From personal experience, it is known that the microgravity environment is an exhilarating experience and can in some cases be overwhelming for some individuals. By going through a full systems engineering process beforehand and having written procedures to follow during the flight phase of the experiment, the students will enjoy a smooth and relaxing microgravity experience, in addition to high quality data that will help in the validation of this key cryo-cooler technology.

"ESMD develops the capabilities and supporting research and technology that will enable sustained and affordable human and robotic exploration and ensure the health and performance of crews during long-duration space exploration, including robotic precursor missions, human transportation elements, and life support systems." -Scott Horowitz, Associate Administrator, Exploration Systems Mission Directorate Along these lines, the VASIMR line of plasma rockets will enable significant improvement to the current line of chemical-based spacecraft transportation from Low Earth Orbit to the Low Lunar Orbit, Near Earth Object orbits, and someday Low Martian Orbit. In the near term: The VASIMR line of thruster prototypes and spaceflight qualified thrusters will be an enabling technology that will make possible new cargo delivery missions to the Moon. A full power VF-200 device will be capable of cargo delivery with twice the payload capacity from low earth orbit to low lunar orbit In this way, the VASIMR project supports the development of a lunar outpost, as planned by NASA and outlined by ESMD, by significantly improving NASA's ability to deliver cargo the lunar surface in support of a sustained human and robotic presence. In the longer term: It is envisioned that there will be very high power VASIMR thrusters, ~MW, delivering cargo and crew to Near Earth Objects, and perhaps Martian orbits in timeframes and payload capacities that significantly improve on state-of-the-art chemical propulsion methods. One step at a time: The VASIMR VF-200 will serve as a "Pathfinder" mission to utilize the International Space Station as a national laboratory. The VASIMR VF-200 would be the first entirely-private funded experiment to fly to the ISS for this purpose. The microgravity cryo-cooler experiment outlined in this SEED proposal will validate a key VASIMR technology in preparation for the first full power space test of the VF-200 device.

NASA Technical Contact: Benjamin Longmier – Johnson Space Center

## University of Toledo: Toledo, Ohio

Sharps Containment
Gravity Type: Micro

The ISS Med Kits are in need of a method of containment for used sharps. The device must be able to contain small sharps (eg used needles) as well as larger sharps (eg used scalpel). The device must also be able to contain small amounts of liquids (eg broken/leaking hypodermic needle). The device must be able to contain the sharps in 0-g and prevent its contents (liquid or solid) from floating out when the container is opened for use. Keep in mind that the sharps will be considered biohazard items and thus cannot be allowed to float free and touch/injure the crew member. The device can be COTS (Commercial Off The Shelf) or modified COTS which would enable the students to gain knowledge about conducting trade studies and meeting stringent requirements. The safe containment of potential contaminants will be a key concern for continued human habitation in space.

NASA Technical Contact: Jasmin Lindo – Johnson Space Center

## University of Wisconsin at Madison: Madison, Wisconsin

Demonstration of Lunar Regolith Handling Technologies in Lunar Gravity
Gravity Type: Lunar

NASA's plans for a lunar outpost (lunar base) will depend on the success of In-Situ Resource Utilization (ISRU) technologies that will process the lunar regolith (soil) to extract important consumables such as oxygen and water. The viability of these process technologies depends critically on a reliable materials handling infrastructure of the lunar regolith. Storage with controlled discharge and beneficiation (conditioning) of the lunar regolith are two key aspects under study at the NASA Glenn Research Center. Two concepts being considered are hoppers and cyclone separators using recycled gas. Of interest are hopper designs which offer improved flow performance and optimized weight and volume. Passive or active flow enhancers can be used to limit the size of the hopper outlets, thereby overall size, and ensure continuous flow and efficient discharge of material. For size beneficiation, cyclone separators using limited amounts of recycled gas could be used to provide size sorting capability down to small particle size ranges. The SEED program provides a valuable opportunity to test the feasibility of developmental concepts under reduced gravity levels, as well as for the next generation of engineers to participate and provide engineering input into NASA's lunar missions. The ISRU project is interested in demonstrations in reduced gravity of these cyclone separator and hopper concepts. The cyclone separator hardware will need to show capability of sorting in three particle size ranges: 30-75 microns, 75-150 microns, and 150-500 microns. The demonstration hardware must use recycled gas at different operating pressures, and will be used for comparison in both 1-g and 1/6th-g (lunar gravity) testing. The hopper hardware will need to separately demonstrate the performance of several flow-efficient geometrical designs and powered enhancement mechanisms. Multiple hoppers units or, if feasible, several replaceable outlets components or powered mechanisms in one or more base units can be used. NASA will provide additional details during the development of the flight hardware.

NASA Technical Contact: Juan Agui – Glenn Research Center

## Washington University in St. Louis: St. Louis, Missouri

Removal of Lunar Regolith from Solar Panels
Gravity Type: Lunar

This project is a continuation of a very successful SEED project from last year, which investigated the effectiveness of tilting and vibration to remove lunar regolith from solar panels. The data from the last experiment shows that this is an effective method, but more data on different combinations of angle of tilting and vibration is needed to make conclusive results. The group performing this experiment would need to design an experiment to tilt solar panels to varying angles, both with and without vibration, to determine how to best remove lunar regolith which gathers on solar panels. Additionally, the group should explore possible ways to statically charge the dust to more closely mimic lunar conditions.

This project involves systems engineering in the overall project definition, requirements, build, and test cycle. In addition, the project works with multiple disciplines of engineering and requires the integration of various components.

In creating a long term lunar base, it is inevitable that lunar regolith with settle on solar panels. In order to successfully power the planned lunar base, a method will be needed to remove this regolith from the panels to allow optimal power production.

NASA Technical Contact: Juan Agui – Glenn Research Center

## Yale University: New Haven, Connecticut

Apparatus Development for 3D Cell Culture in Microgravity
Gravity Type: Micro

***Students from Yale University monitor their experiement in parabolic flight.***

The main goal of this project will be to develop, test, and verify the functionality of a culture apparatus that will allow for the growth of these 3D cultures in microgravity while maintaining an air-liquid interface.

Esophageal cancer is the 6th leading cause of cancer death worldwide. Development of this disease is associated with a variety of risk factors, including tobacco use, heavy alcohol consumption, human papilloma virus infection (HPV-16 and -18) and dietary factors—mineral (molybdenum, selenium, zinc) and vitamin (A, C and E) deficiencies. In addition, a link between esophageal cancer and exposure to ionizing radiation is revealed by the high excess relative risk for squamous cell carcinoma of the esophagus amongst the tumor types observed in longitudinal studies of the survivors of the atomic bomb detonations in Japan. It is also observed as a secondary cancer in patients who received radiotherapy for breast and thoracic cancers, and patients with head/neck and oral squamous cell cancers are at increased risk for metachronous esophageal squamous cell cancers. Esophageal cancer is rapidly fatal, mainly because it remains asymptomatic until late, advanced stages when the disease is rarely curable. Because there is a strong link between radiation exposure and the development of esophageal cancer and the high mortality associated with this type of malignancy, it is essential for cancer risk assessment in astronauts to understand the molecular mechanisms of radiation-induced initiation and progression of esophageal squamous cell carcinoma.

To address these issues, we have initiated preliminary studies using a unique three-dimensional (3D) organotypic model (a form of human tissue engineering) of human esophageal epithelial cells and genetic variants grown in co-culture with human esophageal stromal fibroblasts. Three-dimensional human tissue cell culture models like these are advantageous systems for study of radiation effects including DNA damage repair, genomic instability, and other carcinogenic processes, as well as for study of combined effects of radiation with other space flight stressors. These 3D models offer advantages over standard monolayer culture systems because they mimic the morphological features, differentiation markers, and growth characteristics of fully differentiated normal human tissue and are reproducible using defined components.

The construction of these 3D models involves various components and cell structures. The bottom “base” layer is constructed by mixing normal esophageal fibroblasts into an extracellular matrix of collagen I and/or Matrigel. These bases are cultured in media (submerged) for approximately 7 days, during which time they constrict due to adhesion and migration of the fibroblasts. The bases are then seeded on the top surface with esophageal epithelial cells and again submerged in media and cultured for 4 days. At this point in culture, an air-liquid interface (ALI) is created by removing media to below the level of the epithelial cells, exposing that top layer of the base to air alone. Once this ALI is created, the bases are cultured for another 7 days. This process triggers differentiation and stratification of the epithelial layers and allows the development of a realistic tissue-like structure. With these 3D models, we can then evaluate how carcinogenesis may develop in a space environment due to a variety of factors, including radiation, stress, nutritional deficiencies, as well as evaluate countermeasures such as drug development.

The creation of the ALI is critical to proper cell development and is a key process in this protocol. However, in a microgravity environment, the problem of maintaining an ALI becomes apparent since there will be no gravitational forces to keep the media from floating to the top of the base. Therefore, students will have to develop, test, and verify the functionality of a culture apparatus that will allow for the growth of these 3D cultures in microgravity while maintaining an air-liquid interface.

This project requires an interdisciplinary approach that integrates basic research with the development of new protocols and modeling techniques. Students will need to demonstrate that customer needs and project requirements are clearly defined, that the design process is well-documented, and system validation is completed based on previously agreed criteria.

The Human Research Program (HRP), as a part of the Advanced Capabilities Division of ESMD, has identified areas where the further research is necessary to mitigate the risks of space flight. These areas include the health effects of radiation, characteristics of the space radiation environment, and possible countermeasures and their efficacy. The 3D model we have utilized will be able to directly address these and other questions including how normal tissue and carcinogenesis are affected by stress, nutritional deficiencies, and the development of countermeasures for these risks.

NASA Technical Contact: Zarana Patel – Johnson Space Center

# NES/SEMAA/MUST – By State

* First Time Participant (institution)



## Bear Creek Middle School (NES): Fairburn, Georgia

### Adhesives in Space – Making it Stick

Bear Creek Middle School is investigating the effectiveness of adhesives in microgravity. Identifying and using adhesives in microgravity/zero gravity has been a challenging task for scientists due to the environment of microgravity. Holding down loose objects in space missions continues to be a problem area. Our students will conduct various experiments to determine if there are one or more substances which may be used as a successful bonding material in a microgravity environment.

Students will work with teachers, business partners and community members to gather research pertaining to adhesives and how these adhesives, including common everyday samples may work with NASA in the area of microgravity. In addition to common adhesives, students will design an experiment to create their own adhesive. During class periods, students will be assigned by groups, with each group focusing on one type of adhesive. Students will compare the strengths of different common everyday adhesives (glue, putty, cement, super glue, double sided tape, etc) to determine if one brand bonds better than the other. They will test these adhesives using different formats to determine the rate at which they bond and effectiveness of strength. During our engagement in microgravity, we will observe the interactions of the adhesives in space and perform strength tests to determine how strong is the adhesive bond when the material bearing the adhesive is pulled away by force.

Our data will be processed in two ways. Initially we will record all data received from our experiments in the class and in microgravity. Secondly, we will analyze the data received to gather useful information and suggest conclusions. Obtaining data from this investigation will be an ongoing process where data is continuously collected and analyzed, looking for patterns in observations, developing explanations and testing our hypotheses.

As we conclude our investigation, evidence will be presented to document any effectiveness of adhesive use in microgravity. The research and investigational procedures performed benefit NASA, other institutions and society in identifying effective bonding to materials using various types of adhesives. As NASA continues to explore life on other planets and as the world seeks new technology, our research will supplement any existing and future research occurring with adhesives.

## Broadmoor Middle Laboratory School (NES): Shreveport, Louisiana

How to Move Liquid Water in Differing Gravities

*Educators from Broadmoor Middle Laboratory School monitor their students' experiement.*

We are investigating the effects of gravity on the flow of water in both reduced and hypergravity environments. Bernoulli's principle states that the total energy of a flowing fluid must remain constant. One form of energy commonly used to flow fluid is that of gravity, or specifically head pressure. We are looking at how Bernoulli's principle and the use of head pressure can address the question and title of our experiment; Do Toilets Flush in Zero G? – Or How to Move Liquid Water in Differing Gravities. Our experiment will investigate the functioning of a 'flapper' type toilet valve in micro and hyper-gravities, and also the effectiveness of electric water pumps in differing gravities.

Our experiment will consist of two distinct, sealed systems. The first will be a closed-loop system with an electric water pump, a water reservoir, tubing and a flow meter. The second will consist of an hourglass shaped arrangement of two graduated tanks containing a specific quantity of water with flapper valves set in the middle. A digital accelerometer will be placed near the other gauges to provide relative gravity readings during operation.

We will collect and record experimental data in the classroom to establish a 1-G baseline and collect as much variable-G data as possible prior to the flight to help with the student's hypotheses. It is believed that without the aid of gravity, the flapper-style toilet valve will not be able to function as the water lacks the gravitational potential energy required to open the valve, while the pump operated system will be capable of operating regardless of the effects of gravity. These two demonstrations will show students how the effect of gravity is crucial to the operation of non-pump operated systems and how gravity alone can provide the energy required to move a column of water.

## Conyers Middle School (NES): Conyers, Georgia

Hydroponically Speaking

On a three year journey to Mars and back, astronauts would lack fresh food.  We think hydroponics, growing plants without dirt, may change this.  More research needs to be conducted with actual plant testing in zero gravity, but we will test the effects of microgravity on an automated water delivery system.  We will build a chamber that will contain pumps that will move "nutrient enriched" water from a storage container, through tubing, onto a sponge.  The sponge will represent our growth medium.

We will conduct classes on the Scientific Method, flow rate, head pressure, solubility, gravity, microgravity, and adhesion.  Then students will create data collection sheets and collect data at 1g.  They will record the amount of time, in seconds, that the water travels from the storage container to the sponge, and how long it takes the sponge to become saturated and drip.  The students will instruct the RGO team on how to use the data sheets and how to run the experiment in microgravity.  We need to know if the pumps are affected by microgravity, so we can adjust the pumping time accordingly.  Too little water could result in lower yield and too much water could introduce "free water" into the interior of the space craft.

We would use our results to learn how to set-up the parameters for a water delivery system in space and what adjustments would need to be made to that system.  Our hope is that once this initial research is done, more research will be conducted on the ISS concerning growing plants in zero gravity.  The end result would be fresh food for astronauts on long missions.

## Dr. Albert Einstein Academy (NES): Elizabeth, New Jersey

Space Tools

To place emphasis on real-world connections in the classroom, students will experience the design process as NASA engineers do every day by analyzing a problem, brainstorming solutions, constructing prototypes, evaluating and revising, and finally presenting their findings.   In this investigation, students will solve the problem of how to secure an astronaut when working with a torque applied tool.  After studying Newton's Laws of Motion, particularly the third law, for every action, there is an equal and opposite reaction, students have come to the understanding that an astronaut may turn rather than a bolt or screw in microgravity when using a wrench or other torque applied tool due to the absence of gravity (weight) to overcome torque.   Students will devise and construct a prototype to secure a person and create an unbalance system of forces so that the force applied on the handle of the tool in addition to the force securing the person would exceed the torque needed to turn a bolt or screw.

In addition to solving the problem above, the students will also modify the tool so that it can be used with space gloves and be tethered. The investigation is given to students as a design challenge. As teams of engineers and scientists, they must create a tool system which will address:

1. How well the tool is used to complete the task of turning screws or bolts and not the astronaut by designing and constructing an astronaut restraining system.
2. How to secure the tool so that it does not float away (tethering)
3. How to minimize hand fatigue when using the tool with space gloves

The teams will design and fabricate a tool and then perform evaluations in 1g, microgravity and hyper-gravity environments. Students have researched the problem stated above through simulations. To demonstrate how Newton's 3rd Law of motion and unbalance forces applies to the targeted problem, students were asked to perform the task of pushing a large object a certain distance. First they performed the task with their feet on the floor and then compared their experience to pushing the object while sitting on a multidirectional wheeled platform. Without friction of their footing, they were unsuccessful in pushing the object. The friction was the additional force needed to create an unbalance of forces in their favor to push the object. Similarly, gravity is the force needed to create the unbalance in forces when turning a wrench. Students have also watched video clips of astronauts during their spacewalks and astronauts retelling their experiences on working with space tools in Nova's special on the repair of the Hubble Space Telescope. After creating the prototypes, the performance of using the tools in 1G and in microgravity will be compared.

- The students will record their research notes, preliminary sketches and results of their testing in their project journals to show knowledge gained through every phase in the process. Data to be collected will include the prototypes' efficiency and effectiveness in microgravity as compared to in 1G (classroom). The objective is to create a system (tool and astronaut restraints) that will allow the efficiency and effectiveness of the tool system to be the same or better in microgravity than it is in 1G. Data will be recorded as observations, performance time in completing a task, and personal accounts from the tool evaluators.

The results of this investigation can be used to understand the differences in working in space as compared to working on earth, and the modifications needed to everyday tools to accommodate those differences. The students' designs will vary demonstrating different methods to address the same problem. The results of the tools' performances in microgravity will indicate which methods are effective and which are not. In addition, through this investigation, students will discover that developing technology for one application may also be used elsewhere similar to NASA Spinoffs; NASA technology originally developed for aerospace use but is found to be applicable to other fields. Results from this investigation in regards to the designs and modifications to minimize hand fatigue which may also apply to tools for people with arthritis or other disabling conditions to the hand.

*Educators monitor their students' experiement in parabolic flight.*

## Ellen Ochoa Learning Center and Charles T. Kranz Intermediate School (NES): Cudahy and El Monte, California

### Impact of Changes in Gravity on the Viscosity of Fluids and Their Interactions

This project will observe fluids of various viscosities and densities and how these fluids interact with each other in varied gravity environments including 1-g, 2-g, and microgravity. Viscosity is a measure of a fluid's internal resistance to flow or a measure of fluid friction and fluids with high viscosity flow more slowly than fluids with low viscosity. The density of a material is defined as its mass per unit volume. At 1-g and at specific temperatures, the viscosity and density of fluids have constant values. In addition, at 1-g fluids with different viscosities interact in a predictable way. This experiment will observe how the behavior of liquids with various viscosities and densities is impacted by changes in gravity. The expectation is that the fluid properties will remain the same, but the experiments will differ in the varied gravitational environments.

By timing the movement of a marble through fluids of different viscosities, students can determine the relative viscosity of the fluids, i.e., the faster the marble moves, the less viscous the fluid. Students will do twenty trials at 1-g for each test fluid. The trial times will be averaged to get the rate of travel of the marble. Fluids will then be ordered from least to most viscous. Water will be our control fluid. Additionally students will determine the density of these fluids at 1-g by determining the mass of a fixed volume of each test fluid. The measurements will be repeated at least three times to assure accuracy. Finally students will mix two of the test fluids of different densities by shaking them in an enclosed container. Students will then observe the separation of the two fluids at 1-g. Students will time the rate of separation as well as observe the interactions of the two fluids, particularly at the interfaces of the suspended particles of one fluid in the other. The trials will conclude when the fluids have either mixed or returned to a separated state. These experiments will be repeated onboard the aircraft during both microgravity and 2-g portions of the flight. The hypothesis is that the marble will be stationary in microgravity and its motion will accelerate in the 2-g environment. For the mixing experiment, the hypothesis is that the fluids will take longer to settle in the microgravity environment and shorter in the 2-g environment. During the flight, all experiments will be videotaped for further analysis.

The second part of our team's project is to study blending of a fluid and a solid in the absence of gravity. In 1-g a blender will swirl liquid in a whirlpool motion. When a solid (e.g. piece of fruit or ice) is dropped into the blender the acceleration of gravity and the whirlpool motion will pull the solid towards the blades at the bottom of the blender. Students will observe how the blender, the liquid and pieces of fruit interact. They will videotape the experiment to document the time it takes for the piece(s) of fruit to reach the tip of the blender blades. This experiment will be repeated in the microgravity environment to see if the fruit will be pulled towards the spinning blades. Students will try liquids of different viscosities, such as pineapple juice, apple juice, cranberry juice and types of fruit such as strawberry, mango and banana to observe any change in rate at which the fruit touches the tip of the blades. Since the blender experiment is primarily observational there will only be 4-5 trials conducted onboard the aircraft. The hypothesis is that the mixing will be slower in microgravity and more rapid in 2-g.

The behavior of fluids is important for many of the systems on spaceships from liquid-fuel supply tanks to fluid management devices for life support. By examining the impact of gravity on viscosity and mixing of fluids we hope to add to the understanding of fluid behavior, which will assist the engineering design of critical systems for space exploration in the future.

## Fernbank Science Center (SEMAA): Atlanta, Georgia

### Fuel Cell Cars: Possibility for the Moon?

In today's vision for living on the moon, several problems are faced. One of the problems will be powering equipment and buildings on the surface of the moon. In considering possibilities for powering such a location, one thought was to utilize the technology of fuel cells. This process uses solar energy and water, which has recently been found in abundance on the moon, through electrolysis to create hydrogen gas and oxygen gas. Then the gases are utilized in the creation of power, enough to move a car. The byproduct, water, can be recycled and used over and over again.

One question that arises is: Will fuel cells work in a microgravity setting? Since this process of electrolysis relies on water being in contact with the metals and in microgravity, water behaves differently: will it work?

What we will build is a display which uses the Thames and Kosmos fuel cell car kit. The car will be mounted on a block with the solar panel facing a lamp. We will turn on the lamp and observe to see if gases are created. Once, and if the process works, we will then prepare the fuel cell to generate electricity. We will monitor the electricity created with a volt meter as well and observe the wheels turning on the car. All of this will demonstrate whether or not fuel cells will operate in a lunar environment.

## Fox Meadow Middle School (NES): Colorado Springs, Colorado

### Space Motion Sickness (SMS) and the Semi-Circular Canals of the Inner Ear

Fluids of different viscosities flow at different rates in a 1-G environment. This investigation will attempt to see if these same fluids flow at different rates while in a simulated micro-gravity environment. We anticipate that by using clear plastic tubing that is calibrated and mounted in various positions, we will be able to measure flow rates during periods of micro-gravity as well as the rate of return (re-settling of the liquid) during hyper-gravity. Our design will be a model of the three axes of rotation and the semi-circular canals of the inner ear. In order to have a sufficient post-flight data analysis we will build two experiments with our students: the primary experiment, which will be designed for the flight; and a second experiment which will serve as a prototype to allow us to test the fluids and collect data in the classroom (the 1-G environment). The data collected from the in-class experiment will then be cross-analyzed with data collected during the flight, in an effort to provide a post-flight analysis and lessons learned.

Our students have hypothesized that the flow rates of the three selected liquids will be different when tested on Earth. They further hypothesize that these flow rates will remain consistent in micro-gravity, but that the distances the liquids may travel and their velocities in the tubing may vary. Their assumption was based on the premise that in positive gravity, downward force and the acceleration rate of an object is constant. Since there is still a small amount of gravitational force present in micro-gravity we feel the flow rates will remain in the same order as tested on Earth, but slower due to the reduction of gravitational force.

# Indian River School and Mascoma High School (NES): Canaan, New Hampshire

Fluid Motion

Students at Indian River School and Mascoma Valley Regional High School chose to investigate the behavior of fluids in 1G, microgravity and hypergravity when the fluid is shot from a water displacement device. Scientific principles relating to trajectory motion and fluid properties will be studied to determine their relationship to and dependence on gravitational forces.

This experiment will involve testing of fluids of 3 different compositions. Fluids will be shot from a device pointed at a target, and observations will be made regarding trajectory motion of the fluid and splatter pattern on the target. The back panel of the containment system will have a grid so that the trajectory can be mapped. Students will also record how the fluid spread after impact. During the experiment, 2 video cameras will be used to film the trajectory and impact. Students have identified that as a part of the experiment design process, they must address how to apply a constant force to the water generation device in order to displace a standard amount of fluid for each trial. They will also work to design a target that will allow for best analysis of the fluid splatter pattern. Students have identified some design challenges during the experiment; equipment failure, experimental consistency when performed in 1G, hyper and microgravity, the time in which the experiment can be performed, and human error.

Students will perform the experiment in 1G in the classroom, and will then analyze and compare the results from their classroom observations to those obtained during the microgravity and hypergravity periods during flight. The data collected and the analysis of the data will increase student understanding of Newton's Laws of Motion, projectile motion, and gravitational influences. From design to analysis, peer mentoring will take place. The high school students will work with 5th graders in experiment design, design of the containment system and analyzing the data. Four AP mathematics students will also mentor the 9th grade students in analyzing the data from a mathematical standpoint.

# Lake View Elementary and North Ridge Elementary (NES): Huntington Beach and Moreno Valley, California

Science is Elementary!

Lake View School students are testing the effect of gravity and microgravity on the behavior of balloons filled with gases of differing atomic mass. They are also testing whether gravity has an effect on the production of static electricity. In normal gravity, balloons will either float or sink depending on whether their atomic mass is greater or less than the earths' atmosphere. The scope of the project is research on the force of buoyancy which enables an object to float or seem lighter and the law of static electricity. Students will fill four different balloons with carbon dioxide, helium, argon, and nitrogen and fasten them to a wooden board using string. By untying the string under controlled circumstances they will be able to record whether they sink or float in gravity. They will then take a balloon filled with carbon dioxide and rub it against their hair and observe the effects of the static charge created by holding it about four inches from their hair. They will make hypotheses about how the same experiment will carry out in microgravity.

We hope to see a significant difference in the behavior of these gases in a microgravity environment. The results will help us to understand how the different materials used on aircraft designed for space travel bring varying benefits. Satellites, balloons, airships, airplanes, and space craft used for scientific research are the vehicles of our future. Our research also potentially has implications in the medical arena as human bodies and the air we breathe is made up of all four of the gases we are testing. The Fourth and Fifth grade Reduced Gravity Opportunity (RGO) Science Club at North Ridge Elementary School is questioning specific T.O.Y.S in relation to microgravity and its effect. The students chose to test a desktop pinball machine, tornado tube, a balloon rocket car, and a sticky gel hand. They are interested in forces, motion, and the trajectory paths and how they will perform in a zero gravity environment. They are also interested in how children of the future will play with toys when people are able to live on planets with various levels of gravity.

The students have discussed the trajectory path of the T.O.Y.S in microgravity and hyper gravity to determine differences in levels of force. In both micro and hyper gravity, the students anticipate the trajectory will affect the performance of all the T.O.Y.S. Through observation, measurement and videotaping, the students will record the path the ball in the pinball game, how the tornado tube performs, how the balloon rocket car maintains its path, and how well the sticky gel hand adheres to a smooth surface.

Experiments with T.O.Y.S will enable the students to develop many different hypotheses in the search for what happens to T.O.Y.S in space. With the knowledge that people are able to live in the Space Station year round, there undoubtedly will be a need for entertainment and stress relief. Researching simple toys offers the opportunity to broaden the scope of learning beyond our world into future possibilities of space travel and life on other planets.

## Robert L. Ford Elementary (NES): Lynn, Massachusetts

Fly Me to the Moon…On a Pendulum

The 5th grade students at Robert L. Ford School are working with pendulums in the classroom. They are observing how the pendulum's mass, angle of release and the length of the string affect a pendulum's period. After some hands on experience the students are wondering, will a pendulum's period be affected in a microgravity and hyper gravity environment? In our classroom the students have made pendulum prototypes and are experimenting with their devices. During the first class trials, students observed the effects of changing the pendulum mass. They are pulling the weight back to the release point and allowing it to swing for five full periods and recording the duration. They are repeating this procedure three times and finding the average of their data for one pendulum period. Once this experimental configuration is complete, they will repeat it twice, adding more mass for each new configuration. For data analysis, the student data will be compiled onto a chart and graphed to visually display the information. The other variables, pendulum length and release angle, will be tested in the same fashion. Only one variable will be tested at a time to ensure that the students observe the effect of each variable independently.

During the flight, we will follow the same testing protocol used in the classroom during the hyper gravity and microgravity portions. We are developing the experimental setups for flight, trying to simplify data collection in the process. The addition of a timer and a video camera will facilitate data recording. In addition, by recording our experiment it will also allow us to bring it back to the students to see the outcome.

Two separate experimental stands will be built. One stand will be used for microgravity, while the other will be for hyper gravity. During the desired gravity field, we will release the pendulum and start the timer. Data will be collected until the pendulum swings through five full periods. The video camera will be recording for the duration of the flight, so data may be analyzed post-flight and compared to the in-flight experimental notes. We can find the time of one period, by watching the video and seeing the time and finding the averages from the data collected during the flight.

We believe that our research will be a huge motivator for students, as well as their parents and community members, to take an interest in STEM careers. We also believe that it will create more interest in our space program and help build some awareness as to NASA's current programs and mission. When we first spoke about applying, the students were saying that they probably wouldn't be picked. Now, after being selected, they are already seeing what a little hard work and determination can accomplish. We want our students to know that it is a big world out there and that they can do anything they want to do as long as they put their mind to it. Also, this experiment is important to the students since it allows them to understand the value of a balanced STEM education.

## San Cayetano Elementary (NES): Fillmore, California

Microgravity Fluid Transfer

*San Cayetano educators explain their students' experiement in the Test Readiness Review.*

Our experiment was chosen by the students of San Cayetano Elementary School. It explores the affects of different gravity conditions on the rate at which fluids of different viscosities can be transferred for one tank to another. The students are in the process of developing a hardware design for their experiment. Once their designs are constructed, they will begin the ground based testing portion of their experiment. During this time, the students will make observations and collect various forms of data. After all ground based testing has been completed, the students will prepare their experiment to be sent to Houston. Once in Houston, the students' teachers will conduct the experiment again while being exposed to a micro-gravity environment. The data collected at this time will then be analyzed and compared, by the students, with the data collected during the ground based portion of the experiment. The students will then use their findings to determine how different gravity conditions affect the rate at which fluids can be transformed from one tank to another. To conclude their experimental process, the students will share their finding with their peers, families, and local community members.

## Sequoia Middle School (NES): Porterville, California

Divert the Asteroid: Save the World

Every day Earth is impacted by objects traveling through space. This project addresses the concept of altering the trajectory of an object, such as an asteroid, using magnetism. Research indicates that this will apply to the twenty-five percent of asteroids that are substantially iron-based. Out of those, seventeen percent have an iron core and eight percent are composed mainly of iron. The project is going to attempt to move an artificially created, iron-based asteroid by using magnetism.

This project will simulate an encounter of an iron-based asteroid with a spacecraft generating a magnetic field with the purpose of changing the asteroid's orbit. An artificial iron-based asteroid will be launched along a path parallel to the floor in microgravity, 1g and 2g's. Magnets will be used to alter the path of the asteroid in each gravity environment. Students will observe Newton's First Law of Motion when they observe how the forces due to gravity and magnetic fields will alter the trajectory of an asteroid. Cameras will be used to record the trajectory.

Using the photographic and video record, students will observe and calculate the change in position of the asteroid due to gravitational and magnetic forces acting on it. This will provide valuable information to the students on the degree of deflection and whether an asteroid's trajectory would actually be affected. The information collected will also tell them how distance from the asteroid will affect the outcome. Using this information, students will be able to determine how close the magnet should be to the asteroid in order to achieve the correct angle of deflection. In the event that an impact is probable, NASA will be the one taking the lead in confronting the challenge. Any early data that has been collected will be invaluable to them when decisions need to be made.

## Motivating Undergraduates in Science and Technology (MUST):

Microgravity Nanowire Team

This team is comprised of students from Cooper Union for the Advancement of Science and Art in New York, Seattle Pacific University in Washington, and University of Akron in Ohio.

*MUST students monitor their experiement in parabolic flight.*

We propose to investigate the properties of ZnO (Zinc Oxide) nanowires produced in microgravity conditions and compare our results with those acquired in the laboratory. In particular, the effect of reduced gravity on the morphology of the samples is of interest. Because crystal and protein growth has seen significant changes in morphology in microgravity, it is feasible that we could see longer, and straighter nanowires, as well as a larger quantity under reduced gravity.

Large quantities (grams) of ZnO nanowires have been grown in laboratory conditions by microwave synthesis in under 100 seconds. This process will use a modified conventional microwave oven. While ZnO nanowires have been grown under terrestrial gravity conditions in numerous ways, including spray pyolysis; flame synthesis; metal-organic chemical vapor deposition; vapor-phase growth; thermal chemical reaction vapor transport deposition; sputter deposition; electrodeposition; sol-gel; aqueous dissolution growth method; atomic-layer deposition; pulsed laser deposition; template-directed synthesis; vapor- liquid-solid; wet chemical method on a substrate; aqueous solution method; and an aqueous solution method without substrate, template, or surfactant; little research has been done in the area of nanowire growth under microgravity.

Our method for growing these nanowires is restricted to the time limit of the plane, thus we have chosen to use the conventional microwave, as opposed to other, more tested methods that take more time to complete. Nanowires have the potential to be used in a wide range of applications, from electronic devices to high capacity batteries. ZnO is very inexpensive and has piezoelectric properties, and thus a highly desirable material. When a piezoelectric material is stressed, a voltage difference is created across the material. These types of materials could be used to harvest energy that is expended during routine daily tasks and possibly be useful as very compact, low-power backup energy sources for both robots and astronauts on lunar or planetary missions. Finally, the mechanism of nanowire production is not thoroughly known; this experiment may help further explain this process.

# TFS/NSTA – By State

* First Time Participant (institution)



## ACTS Team

Using Common Plasma Toys to Investigate Convection

This team is associated with the Princeton Plasma Physics Laboratory in Princeton, New Jersey.  This team is comprised of educators from  Princeton High School in New Jersey,  Notre Dame High School in Lawrenceville, New Jersey,  Riverside Middle School in Evans, Georgia,  William Penn Senior High School in York, Pennsylvania, Canadaigua Academy in Canadaigua, New York and  Toms River High School South in Toms River, New Jersey.

This experiment will investigate the effect of microgravity and hyper-gravity on convection by using two common plasma toys, a plasma ball and a Jacob's Ladder. Under normal terrestrial gravity, the plasma of both rise due to convection. For the plasma ball, the arcs of plasma are formed by a central electrode that ionizes the gas molecules inside the sphere. The plasma heats the gas and they become less dense than the surrounding cooler gas molecules and under the effect of gravity, the differences in density will cause convection to occur. Since the ionized gases conduct current easier, the plasma streams move upward following the path of least resistance. A similar effect happens with a Jacob's Ladder. Using standard video equipment and visual analysis software designed by Vernier, we will record the rate of the rise of the plasma arcs under normal gravity, micro-gravity and hyper-gravity.  Using a custom-built Jacob's Ladder, we will also observe how changes in gas pressure change the convection during each parabola.

## Delaware Agriscience Teachers: Middletown, Delaware

Capturing Carbon from Fossil Fuels and Biofuels: does Gravity Matter?

The Delaware Agriscience Teacher Team is investigating how gravity affects the burning of a fossil fuel and a biofuel and the amount of carbon dioxide released during the burning of each.  The title of our investigation, "Capturing Carbon from Fossil Fuels and Biofuls: Does Carbon Matter?" addresses this question.  We will explore this question and determine if gravity has an impact on the amount of carbon released in simple burn of a wick saturated in kerosene and a wick saturated in ethanol.

Our experiment will consist of two parts.  The first part will be collecting the data while in the air.  We will be collecting several things, specifically how much carbon dioxide is released by burning kerosene (a fossil fuel) in a 0G, 1G, and 2G environment.  We will do this by collecting while the plane is leveled out, when the plane is on the ascending portion of the parabola and when the plane is on the descending portion of the parabola.  It is vital that we collect a series of data points at 1G to eliminate the variable of reduced air pressure from our experiment.  The air pressure on the plane will be slighly less than on the ground so this must be done to establish the 1 G baseline.  The 0 G and 2 G will be our variable data.  We will then collect carbon dioxide by burning ethanol (a biofuel) in 0G, 1G, and 2G environments as well.  Once we have collected the carbon dioxide emmissions on the plane, we will execute the second part of our experiment, which is to perform basic titrations on the ground to determine how much carbon dioxide was collected during each burn. We will have a portable video camera to also capture footage of how the burning of a fuel, specifically, the flame changes as gravity changes.

We will collect and record experimental data in the classroom as well to determine if the 1 G baseline on Earth is different than the 1 G baseline on the plane. We will also use this data to help formulate students' hypotheses. It is believed that without gravity, the flame will burn significantly different. However, student opinions vary on how this will effect carbon dioxide emmissions. Some believe that it will produce more carbon dioxide and some believe that it will produce less carbon dioxide. Previous trials of this experiment in the classroom have provided data to show that carbon dioxide emmissions from the fossil fuel and the biofuel are very similar, thus disproving a previous theory that biofuels burn 'cleaner' than fossil fuels in regards to carbon dioxide being released into the atmosphere. Students hope to see if there are any differences in that while at 0 G and 2 G and how this might impact future advances in technology regarding global warming and climate change. This type of study will help to reinforce 'thinking outside the box' regarding our world's energy crisis.

## Dover High School: Dover, Delaware

### Is it Easier to Make a Field Goal in Microgravity?

The Dover High School Stem Team is investigating the effect of microgravity on making a field goal using a catapult device to represent the person kicking the field goal. Students made a prediction that the object being kicked (propelled by catapult) would travel in a straight path without the influence of gravity and hit higher on a field goal target than the same kick on the surface of the Earth in their classroom Science lab. Students also predicted if the data was collected in hyper gravity, the object propelled would hit lower on their field goal target because of the additional gravitational pull.

*Educators from Dover High School monitor their experiement in parabolic flight.*

The Dover High School Stem experiment will consist of two catapult devices built by the students, one using a mousetrap and another using a spring as the elastic potential energy source. In both devices, the object being propelled is a wooden marble covered with Velcro that will stick to a felt target simulating the actual field goal. A point value is given to hitting the target in different locations and students will collect and record data in their Science classroom the weeks of May 24 and May 31, 2010 at Dover High School.

The same catapult devices will be used to collect data in micro gravity. All variables are the same as what was used in the classroom and the same experiment will be done in micro gravity. Using the data collected, the Dover High team will examine the influence of decreased gravitational force on the accuracy of hitting a targeted area.

## Einstein Fellows

### Orientation Using Control Moment Gyroscopes (CMGs)

This team is comprised of educators from Eagle's View Academy in Jacksonville, Florida, Blanco Middle School in Blanco, Texas, Oakcrest School for Girls in Mclean, Virginia, Burlington County Institute of Technology in Medford, New Jersey and Palm Beach County School District in Palm Beach, Florida.

The Einstein Fellows (EF) Educator Team proposes to investigate Control Moment Gyroscope (CMG) slew rates of a 1U CubeSat during periods of microgravity aboard the Zero G aircraft. CMGs have demonstrated effective attitude control on spacecraft including the International Space Station (ISS). CMGs utilize the principle of Conservation of Momentum to produce a torque along an internal axis of rotation. This allows for spacecraft attitude control without loss of mass. Aerospace engineer researchers are interested in the demonstration of effective attitude control via miniaturized CMGs.

The 1U CubeSat will be flown in a tall glovebox aboard the Zero G aircraft. The CubeSat willcontain an accelerometer and an internal recording device. The CMGs will be at operational speed (4,500 rpm) prior to the weightless parabolas. Using a FlipCam and digital camera, CubeSat motion will be recorded. A Vernier LabQuest and 3-Axis Accelerometer will also record

the background inflight data. The slew rate data will be retrieved postflight from the Inertial Maneuvering Unit (IMU). This experiment will compare CMG CubeSat rotation data in freefall with the CubeSat rotation data in 1G collected in the Spacecraft Orientation Buoyancy Experiment Kiosk (SOBEK) environment.

The CubeSat is an excellent vehicle for connecting basic principles of physics to the real-world applications such as the motion of satellites. Students will apply gyroscopic principles in stabilizing spacecraft attitude to accurately control orientation, or rapidly point onboard instrumentation and sensors at a georeferenced Earth-bound target.

## Fairport High School: Fairport, New York

### The Effect of Gravitational Changes on Electrochemical Cells

The purpose of this study is to evaluate electrochemical cells and the effect different gravity conditions have on voltage production. An electrochemical cell converts chemical energy into electrical energy by pairing two metal electrodes of different reactivity in an electrolyte solution. Our experimental setup will consist of four cells per flight. Two of the cells will contain aluminum and copper electrodes while the other two will contain zinc and copper electrodes. Each cell will contain varying concentrations of electrolyte solution. The metal electrodes are joined by a wire that will be attached to a digital voltmeter. The experiment will investigate the impact of electrolyte concentration and type of metal electrode on voltage production in a reduced gravity environment. The voltage data collected during the reduced gravity flight will be compared to voltage data collected by the students using the same variables in the 1G environment.

## Fulton High School: Fulton, Missouri

### Bubble Jeopardy: Does Gravity Effect Reaction Rates?

This is experiment is designed to test the effects of gravity on reaction rates. A chemical reaction takes place at a rate that depends on factors such as temperature and concentration of reactants. In order for the reaction to take place, the particles in the two substances must come into contact. Will gravity affect this?

The reaction we will be using involves combining Alka-Seltzer and water. The reaction that will take place is an acid-base reaction between the ingredients of the Alka-Seltzer when mixed with water (sodium bicarbonate and citric acid). We will be measuring the rate of reaction in 1-g, 2-g, and microgravity environment to determine if changes in gravity affect the interactions of particles and thus the rate of reaction.

The time it takes for the reaction to complete will be measured. In addition, the amount of gas that is produced in the reaction will be measured at a certain time after the reaction has begun. To measure these quantities, an apparatus consisting of two syringes connected at the tip will be used to combine the substance to start a reaction. A video camera will record the reaction for later analysis of time. When the predetermined amount of time has passed, the volume in the syringe where the reaction is happening will be recorded. Several trials in all three gravity environments will be conducted. Students will conduct the trials in 1-g. The flight team will conduct the trials in 2-g and microgravity. If gravity has an affect on reaction rates, we will see a difference in data collected from one gravity environment to another.

## Greensboro Day School: Greensboro, North Carolina

### Hooke's Law Orbits

This experiment will explore the behavior of two masses, connected by a spring and set into rotation in simulated zero gravity, resulting in orbital motion. The experimental apparatus will consist of a custom-built turntable that will accelerate a mass-spring-mass system to a predetermined angular speed, about an axis perpendicular to the spring, before releasing it during a zero-g interval. A video camera will record each run, allowing frame-by-frame analysis of the masses' trajectories.

At a glance, this experiment will appear to be an analog of a binary star, where gravity between the two stars causes them to orbit their common center of mass; or a hydrogen atom, where the electrostatic attraction between the positive proton and negative electron serves the same function. Gravity and the electrostatic force both get weaker as the inverse square of the distance. In our experiment, however, the spring is providing the centripetal force, and that force increases with distance, in a linear relationship described by Hooke's Law. Having a dramatically different force law will allow us to explore aspects of orbital motion that are universal to all rotational motion (such as conservation of energy and conservation of angular momentum) and those that are dependent on the nature of the central force (such as Kepler's Laws for gravitational orbits.) For a 2-body system, the gravitational force results in elliptical orbits; we anticipate our Hooke's Law orbits to be Lissajous figures, such as created by the classic Spirograph™ toy. In the event the spring buckles at its minimum length, the motion will become chaotic.

We plan test a variety of system parameters. We will use several different springs (with varying stiffness and damping parameters), varying masses, equal and unequal masses, and varying initial stretches of the spring and angular velocities.

## Jackson High School: Jackson, Missouri

### Does Zero-Gravity Affect the Rate of Transformation in E. coli Bacteria?and the Effect of Varied Gravity on the Flow Rate of Liquids

*Educators from Jackson High School monitor their experiment in parabolic flight.*

Transformation has long been known as one of the few options that prokaryotes have for achieving genetic diversity. Lacking the options of random combining of gametes during sexual reproduction as well as cross-over of homologous chromosomes, bacteria have diversified very successfully by absorbing "orphaned" rings of DNA called plasmids (transformation). By this process, they exchange various survival-enhancing genes such as resistance to antibiotics. This ability of germs has concerned the medical community for decades as strains of pathogenic species such as Staphylococcus aureus have developed that are resistant to all but our most potent antibiotics.

Escherichia coli is a commonly used organism for microbiological research. Transformation in the laboratory has been enhanced by the addition of $CaCl_2$ to liquid media and heat shocking cells at 42∘C momentarily, making the cell membrane more permeable to plasmids. The entire transformation process takes a matter of seconds. JHS students have performed experiments with E. coli for many years and have decided to explore this aspect of that species' life cycle.

We propose to measure the rate of transformation of E. coli using at least three plasmids of varying masses. The independent variable is mass of each plasmid, all of which contain the ampicillin-resistance gene (ampr). The dependent variable is the rate of transformation, as measured by the growth of colonies on ampicillin agar post-flight. In addition, we hope to measure the rate of transformation at hyper-gravity (gravity-relevance). We have discussed the dynamics of switching the experimental groups from the ice pack to the heating block and believe we have a workable plan, although it will involve some equipment modifications. As a control, we propose to conduct the same experiment on the ground, hopefully at the same time as the zero-gravity experiment is going on.

Our hypothesis is that there will be no statistically significant difference between the transformation rate (Rt) of zero-G cells compared to the control group, and that there will be a statistically significant difference in the Rt between the hyper-G experimental group and the control group. In other words, we expect the E. coli cells to become separated from the lower-mass plasmids at hyper-gravity before they can absorb them.

All materials are non-pathogenic and are readily available to and used by schools world-wide. The results of this investigation in astrobiology may be applicable to future research in medicine and pharmacology. As part of our background research, we have briefly scanned the book An Astrobiology Strategy for the Exploration of Mars by the Committee on an Astrobiology Strategy for the Exploration of Mars and the National Research Council. If our proposal is accepted, we will study the volume more closely to determine what effect our research may have on the likelihood of Martian life. Since transformation is necessary for the variation that promotes natural selection within terrestrial microbial populations, we infer that the same would be true for extra-terrestrial microbes as well.

I must admit that I like to have various toys in my classroom. One of the toys I have is a tornado tube. When the opportunity for a reduced gravity flight came up, it naturally made sense to go back to the tornado tube since we looked at it when we discussed how gravity affects mass. In a tornado tube turbulent flow is used to move a liquid. The tornado tube connects two 2-Liter bottles. When the water in the top tube rotates, gravity pulls the water down, and at the same time air it pushed up to the top tube.

Our hypothesis is that even in low gravity, if turbulent flow can be achieved, water will still move from the upper bottle to the lower bottle, but the rate of flow will be much slower. Gravity will be the independent variable, while the liquid flow rate will be the dependent variable. We also predict that the flow rated measured during the part of the flight with twice the gravity will be greater than those measured in both low gravity and earth's normal gravity.

In class we plan to put together the tornado tubes, each with the exact same amount of water. In class we can test the flow rate at earth's gravity. Students will be asked to hypothesize what they think will happen on the flight, and explain their reasoning. When the results of the zero-gravity and hyper-gravity are obtained, students will be responsible for analyzing and graphing the data. They will draw conclusions based on their data and observations, such as what type relationship do gravity and rate of flow have, are they inversely proportional, directly proportional, or do they act independently of one another?

The bottle apparatus will fit into the boxes provided for the trip. We will also bring stopwatches to record the rate of flow. As soon as zero gravity is achieved, we will rotate the bottle to try and achieve turbulent flow. With reduced gravity we expect that turbulent flow can be achieved, but the rate of flow will be much slower than at earth's gravity. In hyper-gravity once equilibrium is achieved, be believe that the rate of flow will increase due to the increased gravity.

## Jefferson County, Trussville City Schools, and University of Alabama at Birmingham: Homewood, Trussville, and Birmingham, Alabama

### The Effects of Microgravity on the Rate of a Chemical Reaction

Students and teachers from five high schools in the Birmingham, Alabama area will investigate the effects of gravity on the rate of chemical reactions using the Iodine Clock Reaction. In a chemical reaction, atoms are rearranged and new substances are formed. This process involves energy to break existing bonds and produce effective collisions so new bonds will form. The rate of a chemical reaction is directly related to the number of collisions between the atoms and molecules. As the number of collisions increase so does the reaction rate. The Iodine Clock reaction is an oxidation reduction reaction using sodium metabisulfite, potassium iodate and starch. The first step in the reaction mechanism is the rate determining step and produces iodide ions and bisulfate ions. In the next step iodide ions are oxidized by iodate to form iodine. In the final step iodine reacts with starch to form a blue iodine-starch complex. The rate of the reaction can be monitored by the time it takes for the blue complex to appear.

Students have studied the effects of concentration, temperature and agitation on the reaction rate of the Iodine Clock reaction in the high school laboratory. Their hypothesis is that at reduced gravity atoms and molecules would have freer movement thus allowing more collisions and a faster reaction rate. Through experimentation students have determined the concentrations of reactants to produce a reaction rate of approximately 16 seconds, a target time during the period of reduced gravity. In the experiment the independent variable is gravity and the dependent variable is time. The controls are concentration of reagents, volume of solutions, force of mixing, and temperature of the surroundings. Students have devised an apparatus using two syringes and tubing for the reaction vessel. Multiple reaction systems will be mounted on a board in order to obtain significant data during the reduced gravity flight. The time required for the appearance of the blue complex at reduced gravity will be compared to the times collected in the high school laboratory. Students want to determine if gravity is strong enough to influence the collisions between atoms and molecules. Knowledge of this is important in studying and planning for work in space.

## Muscogee County School District: Columbus, Georgia

### Find and Center Testbed (FACT) Satellite Capability Experiment

The FACT Satellite Capability Experiment will use the Cubesat form factor to complete an engineering proof of concept for a new way for a free floating apparatus to find and center itself on a known source. This experiment will create motion using a control moment gyroscope built by the student team, but this is not the experiment. Using a quad cell photodiode with a laser printed opaque line over it; the Cubesat model will turn itself to minimize a shadow cast by the light of a known source. The known source will be placed in different locations per trial and will blink at 38 kHz and the Cubesat quadcell photodiode input will be filtered to only recognize this source. This new way of allowing an autonomous system to align itself with known sources could have many applications to space science technology. Personal Satellite Assistants could hold near perfect alignment to help astronauts do work inside or outside of their spacecraft. Small satellites could align themselves with other small satellites to maximize their communication link and allow them to perform more like the larger typical spacecraft at a much cheaper cost.

## New Deal High School: New Deal, Texas

### Motion in Two Dimensions

We are investigating the effects of gravity on the motion of objects through projectile motion and momentum experiments. Gravity is a constant that affects all motion. The paths of objects in both reduced and hyper gravity environments will be studied.

Our investigation is in two parts. The first experiment is projectile motion. We will study the path of a projectile in zero-gravity and hyper-gravity. A steel marble will be launched from a spring-loaded launcher. Its path will be noted and data will be collected. The second experiment will involve two of the marbles colliding with each other. The paths of the marbles before and after the collisions will be observed.

We will conduct the experiments and collect data in the classroom under normal gravity conditions prior to the flight. Then compare and analyze the results with the zero-gravity data. These experiments will show students that gravity is crucial in the development of important physics concepts, confirm the basic kinematic equations that are learned in science, and foster an interest in science, math, and engineering fields.

## Northbrook High School: Spring, Texas

### Analyzing Capillary Action in Tubes with Different Diameters and Fluids

The purpose of our experiment is to analyze capillary action, surface tension and viscosity in tubes with different diameters and fluids in microgravity environment compare to earth gravity. Our hypothesis is that in going from normal gravity to microgravity, capillary effects will cause fluids in the tubes to rise. We hypothesize that fluids in narrow tubes will climb more slowly compared to wider tubes in Zero G flight.

Our experiment set up contains nine different size capillaries, three acrylic containers (Each acrylic container used to hold three clear plastic vials which contain three liquids with holes on the top to fit a capillary tube) and Velcro used to secure acrylic box in the glass box. The three liquids will be distilled water, canola oil and silicon oil.

The smallest diameter tube is closed at the top; we did not expect any rise in this tube because the pressure rise in the air above the fluid would negate the capillary flow.

This experiment will form the basis of high school lesson plans, which we will use in coordination with our pre-existing science outreach projects and science activities.

## PARSE Team: Jersey City, New Jersey

### Investigations of Complex Fluids in Microgravity

This team is associated with the Princeton Plasma Physics Laboratory in Princeton, New Jersey. All the educators on this team are with Saint Peter's College in Jersey City, New Jersey.

Complex fluids such as foam or even blood exhibit behavior characteristic of two or more states of matter. This study of complex fluids in microgravity seeks to analyze the multi-phase phenomena often masked by the effects of gravity. For this experiment, we will use corn starch, shaving cream, and "slime" contained in transparent chambers that will allow for three dimensional visual observations. Charged-coupled device (CCD) cameras will be used to observe and record the macroscopic behavior of various characteristic complex fluids. Sound wave amplifiers will be used to apply controlled acoustic pressure on each fluid. Aside from the scientific work, results will be use to develop new educational curriculum for high school physics and chemistry classes centered on states of matter.

*PARSE Team Educators monitor their experiement in parabolic flight.*

## Van Alstyne High School: Van Alstyne, Texas

### Microgravity Effects on Polyurethane Reaction Rates and Formation

This experiment will explore the reaction rate and formation effects of microgravity on two part polyurethane foam formation. The two components will be kept separated in a closed chamber in equals amounts (2cc each of "part A" and "part B") until the zero G portion of the flight. At the onset of the zero G portion of the flight a small DC motor will be engaged for 3 or 6 seconds. Half of the test will be done at 3 seconds and half at 6 second so that we can compare the results of different mixing times. The motor will power a mixing "blade" (plexiglass) that will beak the plastic seal on the components and mix the components. As the reaction occurs the temperature using a 20 k NTC Thermistor feeding data to a Vernier LabQuest data collection device. The expected maximum temperature is 56 o C. At the same time any changes in pressure will be recorded using a Vernier Gas Pressure Sensor GPS-BTA. The maximum pressure delta is 1 psi. Also, the foam expansion and formation will be recorded using a video camera. The same procedure will be done in the 1G environment on the ground and compared with the microgravity results.

# Appendixes


**Top, left:** Students from Carthage College taking data from their team's experiement. **Middle, left:** Educator takes a parabola to work with a slinky. **Bottom, left:** Students work with their NASA Principal Investigator to collect data during the flight. **Top, right:** The view out the aircraft window during a parabola. **Middle, right:** Flight team members are troubleshooting a computer issue mid-flight. **Right, bottom:** Educators from Conyers Middle School in Georgia work their student's experiment in flight.

# Appendix 1 – Undergraduate Student Program Proposals at a Glance

## Selected Engineering Proposals

| Institution | Proposal Title | Page |
|---|---|---|
| Austin Community College | SRED - Smart Resistive Exercise Device For Free Weight Simulation In Microgravity | 6 |
| Embry-Riddle Aeronautical University (Daytona Beach, FL) | Project HORIZONS (Harmonic Oscillations Resulting in Zero-G On-axis Nutation of Spacecraft) | 7 |
| Embry-Riddle Aeronautical University (Prescott, AZ) | Preliminary Research for Inertia Matrix Estimation (PRIME) Satellite | 7 |
| Purdue University | Effect of Textured Surfaces on Bubble Detachment and Contact Area in Microgravity | 8 |
| State University of New York at Buffalo | Relative Attitude Determination for Satellite Formation Flying | 8 |
| University of Michigan | Exploring the Design Space of the Dry Configuration of the Nanoparticle Field Extraction Thruster in Microgravity | 9 |
| University of Michigan | Evaluating the Extendable Solar Array System in a Microgravity Environment | 9 |
| University of Washington | Rotational Damping of Slosh in Microgravity | 9 |
| University of Wisconsin at Madison | The Influence of Frequency on the Performance of Ultrasonic Enhancement of Liquid Convection Cooling in Variable Gravity | 10 |
| Utah State University | FUNBOE Follow-Up Nucleate Boiling On-flight Experiment | 10 |
| West Virginia University | Controlling Fuel Sloshing Through the Use of a Ferromagnetic Solvent Manipulated via an Electromagnetic Field | 10 |

## Selected Physical Science Proposals

| Institution | Proposal Title | Page |
|---|---|---|
| The College of New Jersey | Using Fluorescent Dust to Obtain a Three-Dimensional Analysis of a Dusty Plasma Part III | 6 |
| Yale University | Crystalline Structure Transformation in Complex Plasma | 11 |

## Selected Life Science (Including Biology) Proposal

| Institution | Proposal Title | Page |
|---|---|---|
| San Jacinto College North Campus | Further Evaluation of the Effects of Short Term Reduced Gravity on Prothrombin Time of Plasma | 8 |

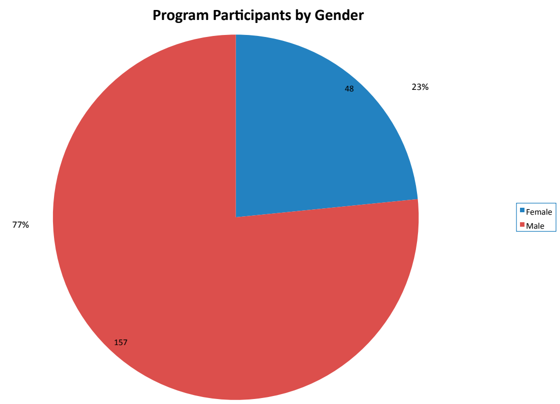
# Appendix 2 – SEED Program Proposals at a Glance

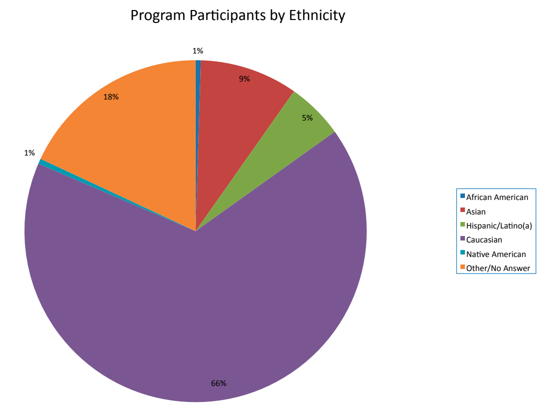
Selected Engineering Proposals

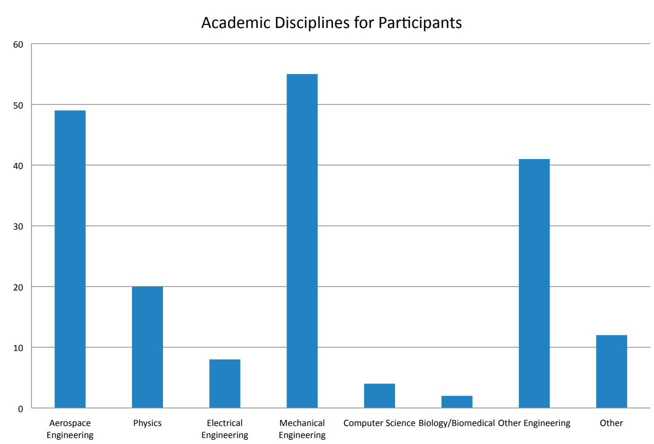
# Appendix 3 – Demographic Data

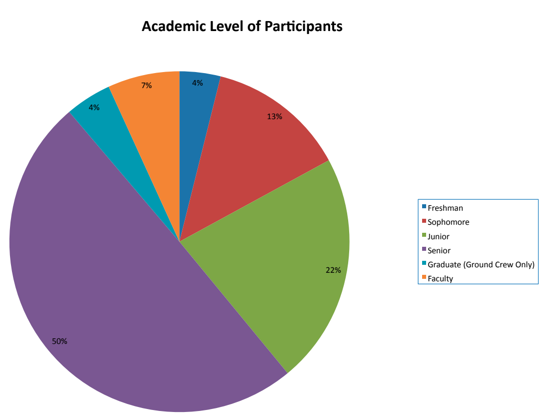
**Top, left:** Students working on the experiment during a parabola. **Middle, left:** University of Michigan students deploying their cube SAT. **Bottom, left:** Students boarding microgravity aircraft. **Top, right:** Flight team floating with their experiment in microgravity. **Middle, right:** Flight team taking a team photo prior to flight. **Bottom, right:** Flight team watching their hardware float in microgravity.

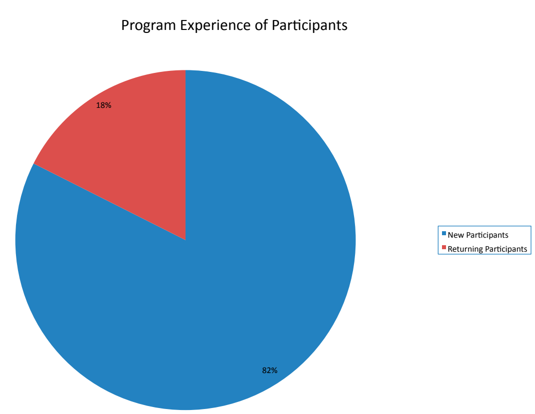
# Combined Undergraduate Students Demographic Information (UG & SEED)



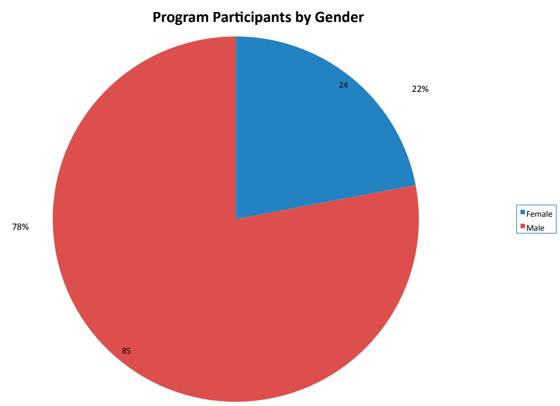



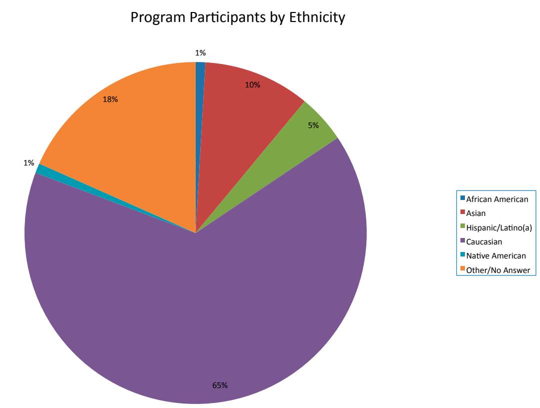



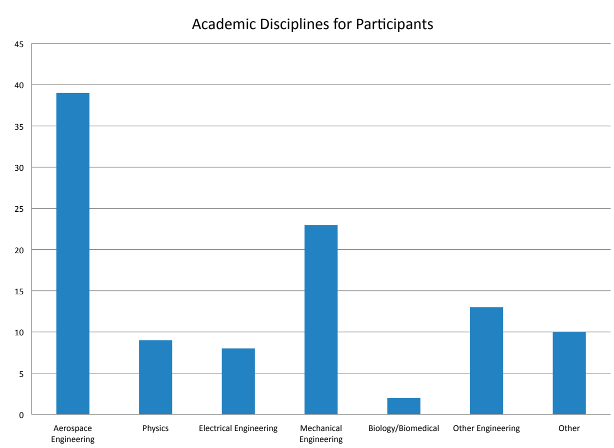



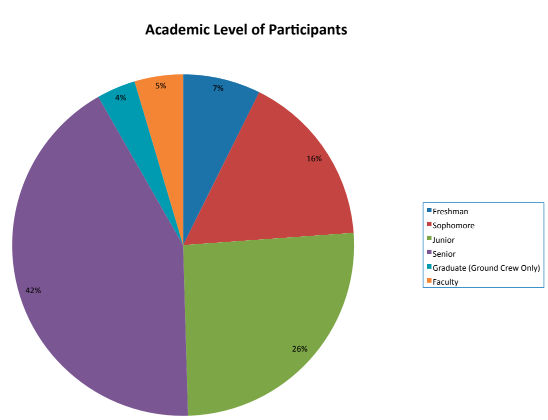



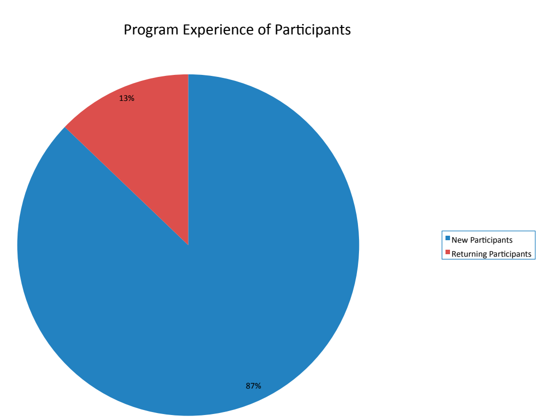
# Undergraduate Student Program Demographic Information



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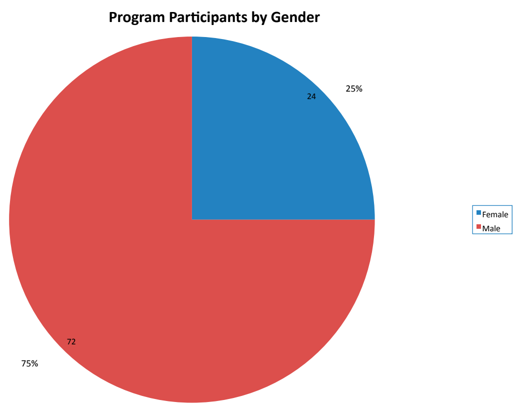
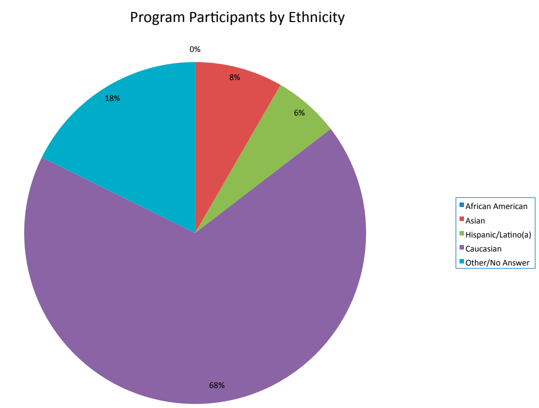
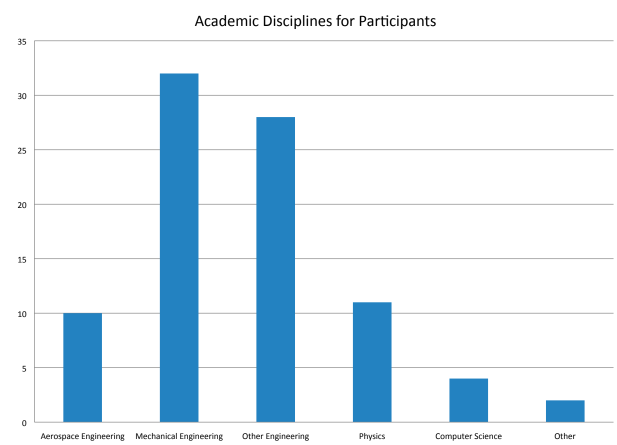
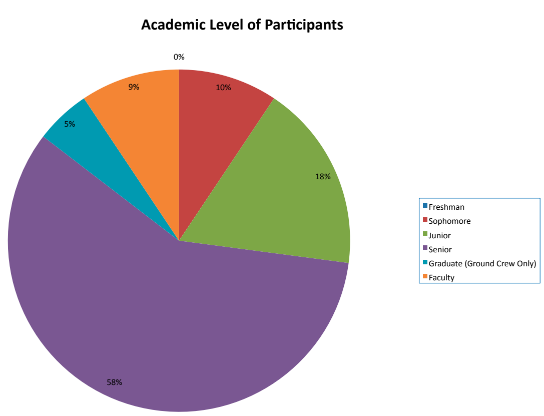
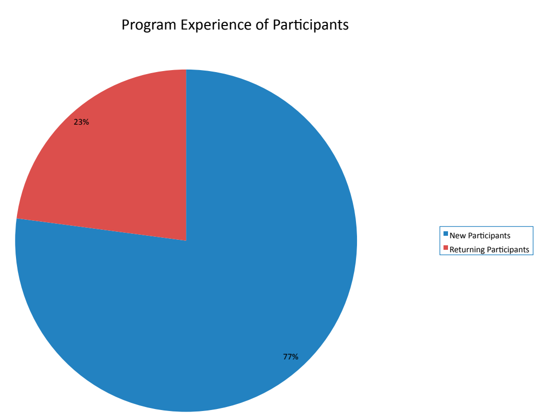


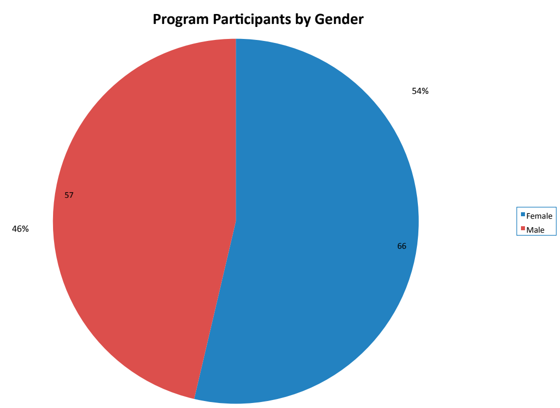



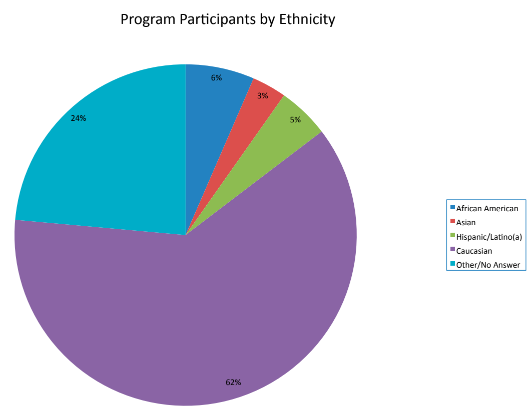



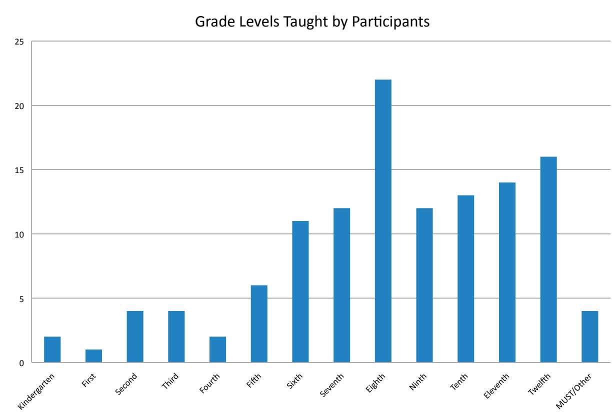



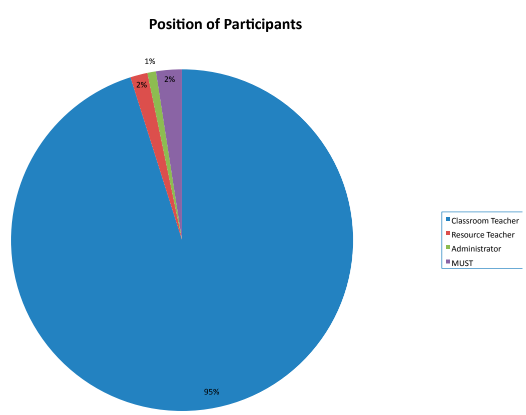



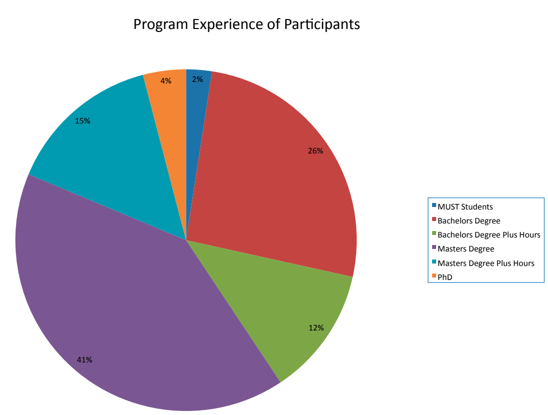
# Combined Educator Program
# Demographic Information (NES/SEMAA/MUST & TFS/NSTA)



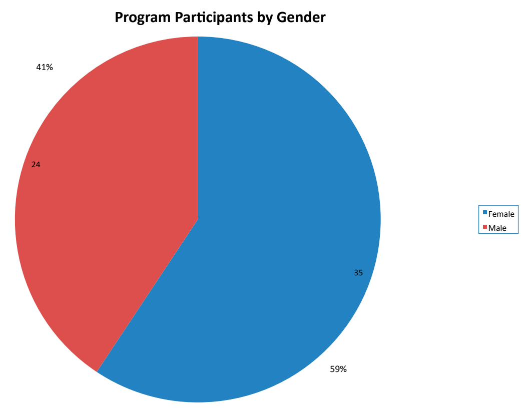



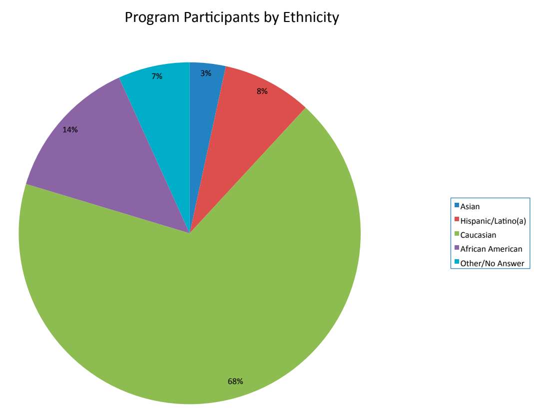



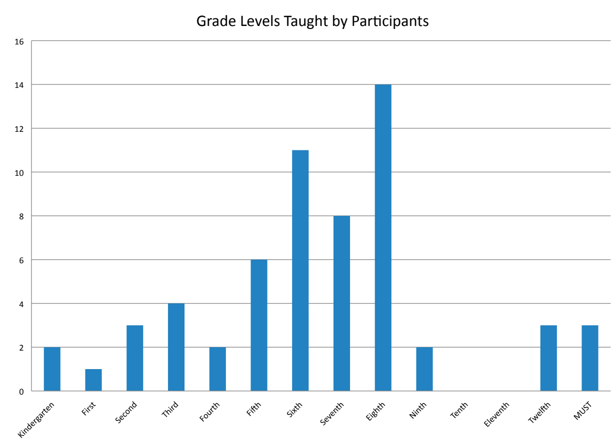



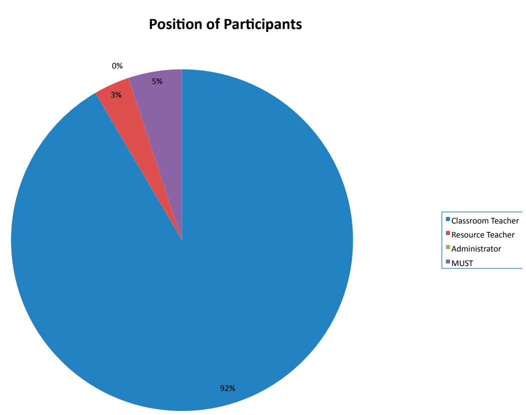



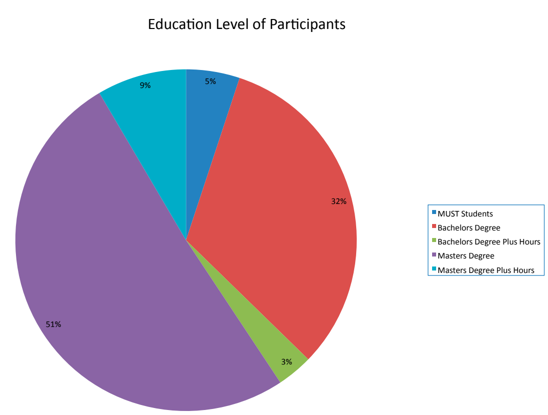
# NASA Explorer School Educators Demographic Information



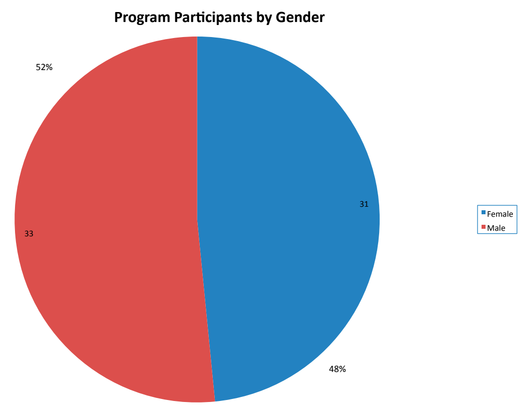



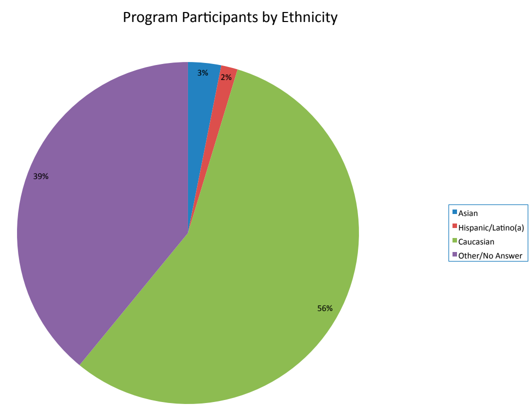



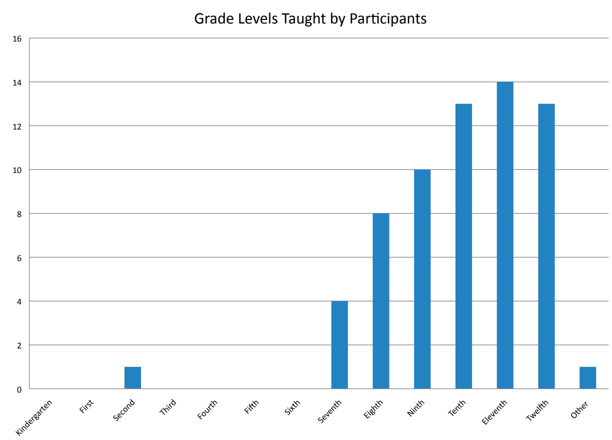



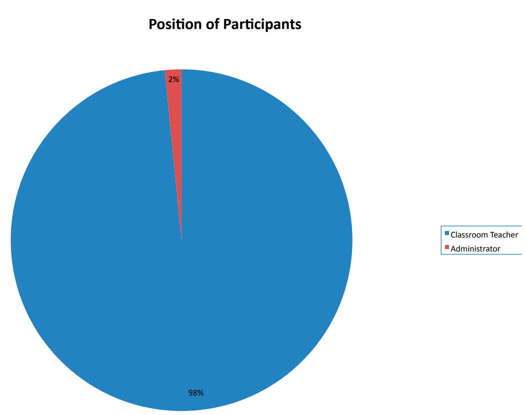



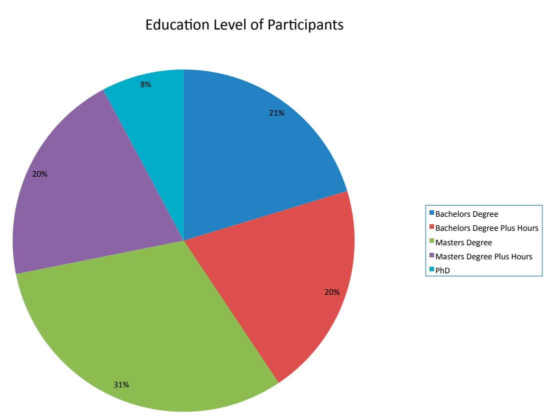
# TFS/NSTA Educators Demographic Information



# Appendix 4 – Participant Comments

Program evaluations were collected post-flight. Educators, students, and faculty overwhelmingly praised the program for providing a rare real world hands-on engineering experience for K-12 and undergraduate students. A few of the educator and student responses follow.

- "I have ended everyday here with a unique sense of accomplishment. The opportunity to tackle an experiment from start to finish, and to do so in this challenging and inspiring environment, is priceless. Arriving with many hours of work behind us and two critical flights before us, the goal is to make the most out of our time here at JSC. RGSFOP does a great job at providing the facilities and support needed for successful preparation and execution of our experiments. The atmosphere is professional and serious as much as it is exciting and fun. This was the first time that I participated in the program and the first time I had engineered an experiment. While here, the program coordinators made sure things were safe and efficient, allowing me to gain invaluable experience and to create amazing memories."

- "I have been involved in this program for the past two years and I believe that this experience has been one of the most valuable experiences of my educational career. It has helped me gain numerous skills which cannot be taught inside the classroom and has motivated me to pursue an advanced degree in my field. The Microgravity University program has helped me to realize my own potential and has opened up a world of opportunities to me. I cannot thank everyone involved in making this program possible enough."

- "Microgravity University has been a wonderful experience for me. I have been involved in the program for three years and each year has provided new challenges and opportunities. The personnel are fabulous; their professionalism and dedication to their work not only makes the program fun and safe, but also has helped me improve my own work and expectations. This has truly been a unique experience. Nowhere else have I been challenged to visualize and implement something so completely and to such high standards. My experience with the program has given me confidence as I begin graduate school next year. Especially for students coming from non-technical schools, this program is a fantastic opportunity for learning all sorts of things about the scientific process that you could never learn in a classroom or even a lab. The trip to Houston also provides a chance to try imagining what might come after their education and has certainly opened my mind to possibilities I otherwise never would have considered. The program also does a good job encouraging the participants to talk about and engage others in the science; this is undoubtedly an invaluable skill. In addition, I have enjoyed working with my peers to both share my own skills and learn new ones. I hope this program continues for another 15 years and more."

- "Great program! I have learned so much and it is a great opportunity to allow undergrads to do research in an appropriate environment for the area of work we are in."

- "Participating in the NASA microgravity university program has been the highlight of my undergraduate education. We receive enormous support from CT Space Grant, the Department of Physics, and the Office of the Dean of Science Education. Additionally, our group has great visibility on campus, especially amongst our scientific compatriots. No other program would be able to comparably develop leadership and technical skills as this amazing opportunity to perform cutting-edge science in a unique operational environment."

- “As a student completing my second year of this program, I have found that it continues to be an extremely enriching experience. The process exposes students to the realistic standards faced in the work place which we would never have otherwise experienced. Though the process was rigorous, it was by far the greatest learning experience that I have had in my undergraduate career, and certainly one of the most memorable. I hope that the program can continue to allow students to experience this process.”

- “NASA’s reduced gravity opportunities have fundamentally changed my educational experience. My specialized knowledge of our project’s, premise led to a greater understanding of, insight into, and enthusiasm for my STEM class work, and the work ethic developed for our RGO project allowed me to pursue those interests with a new vigor and persistence. After completing this project I feel that I am much better prepared to effect meaningful scientific change.”

- “This was an excellent once-in-a-lifetime opportunity that was a great combination of work experience, hands on development, and reward for all the hard work. Sticking strictly to classroom education can be tedious, and this provided another great environment for continuing your education, especially if you took on a part of the experiment, like data acquisition, that is outside your field of study.”

- “Keep this program alive, this gives students an experience that words can’t do justice. And the science collected has the potential to change the world.”

- “This Reduced Gravity program is an extremely valuable and inspiring program. On campus, our team is held in high regard and has inspired many students to take an active role in science and engineering. I have had the opportunity to personally meet with the Chairs of the Physics Department and Engineering Department, learning valuable skills about presenting proposals and applying for funding. The hands-on engineering experience I gained through this program is invaluable to my future goal of obtaining a science degree, and certainly would not have had a similar opportunity to conduct such an experiment with any other program at my university. Finally, the program introduced me to the many internship and educational opportunities at NASA which I plan to take full advantage of. I loved this program and know that it inspires interest in science research and NASA better than any other program I know of.”

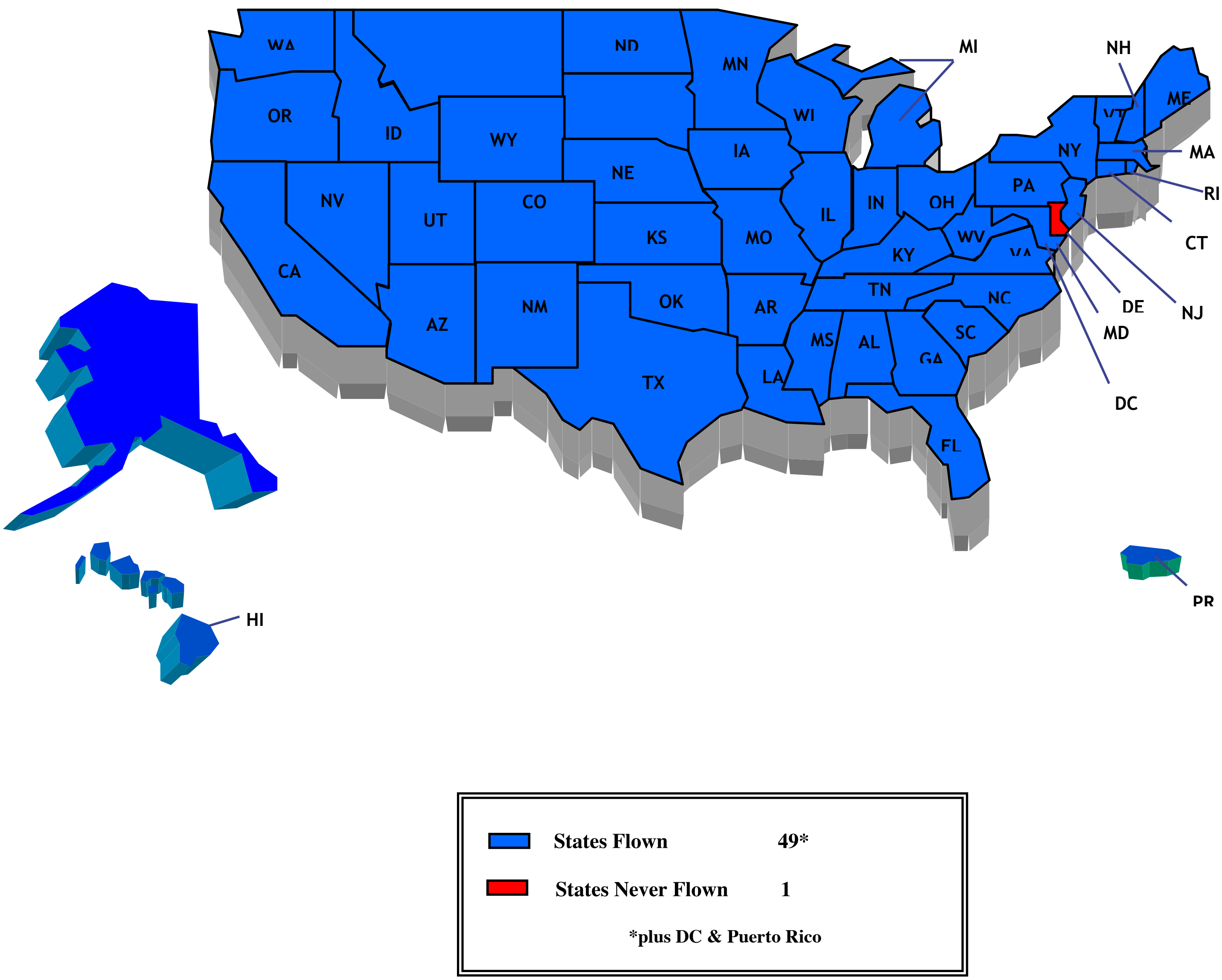
- “There’s nothing else like it on earth and it deserves the highest support and recognition. I have always wanted to be an astronaut and in the current times of change and uncertainty, it was a miracle that this program allowed me to live my dreams. I’m so happy to have been part of NASA in so many ways as a 20-21 year-old: USRP, Co-Op and RGO. Please continue to fund, support, and highlight this program. It’s critical for the next generation of STEM students in our country and world.”

- “The experience was completely unforgettable and quite possibly the most amazing endeavor of my life. I am incredibly grateful to NASA and in particular the RGO staff that made this experience possible. Without this program the industry would lose something that truly inspires and serves as a wonderful reminder of why I will love working as an aerospace engineer.”

# Appendix 5 – Summary Participation

PARTICIPATING STATES: 1997 – 2010

Forty-nine (49) states have participated in the Reduced Gravity Education Flight Program plus DC and Puerto Rico. The one state that has yet to participate is Delaware.



# Appendix 6 – 1997-2010 Participating University Status

3,005 Student Flyers (does not include ground crew)
193 Institutions / 646 Teams / 49 States (plus DC & Puerto Rico)

| Institution Participation: | | | | | |
|---|---|---|---|---|---|
| AK | Univ of Alaska Fairbanks | FL | Florida State Univ | MI | Michigan Technological University |
| AL | Alabama A&M | FL | Saint Leo College | MI | Univ of Michigan |
| AL | Auburn Univ. | FL | Univ of Miami | MI | Univ of Michigan-Dearborn |
| AL | Univ of Alabama-Birmingham | GA | Georgia Institute of Technology | MN | Univ of Minnesota-Minneapolis |
| AL | Univ of Alabama-Huntsville | GA | Morehouse School of Med. | MO | Drury College |
| AL | Univ of Alabama-Tuscaloosa | GA | State Univ of West Georgia | MO | Missouri Univ Sci & Tech |
| AR | Univ of Arkansas | GA | Univ of Georgia | MO | University of Missouri |
| AR | University of the Ozarks | HI | Windward CC | MS | Mississippi State Univ |
| AZ | Arizona State Univ | IA | Iowa State | MO | Washington Univ-St. Louis |
| AZ | Embry-Riddle Aeronautical Univ-Prescott | IA | University of Iowa | MS | Univ of Southern Mississippi |
| AZ | No Arizona Univ | IA | University of Northern Iowa | MT | Dull Knife Mem Tribal College |
| AZ | Univ of Arizona/Florida | ID | Boise State Univ | MT | Montana State Univ-Billings |
| CA | Cal State-San Marcos | ID | Shonshone-Bannock | MT | Montana State Univ-Bozeman |
| CA | California Institute of Technology | ID | University of Idaho | NC | Duke University |
| CA | California Polytechnic Institute | IL | Univ of Illinois-Chicago | NC | North Carolina A&T State Univ |
| CA | Foothill College | IL | Univ of Illinois-Urbana/Champaign | NC | North Carolina State |
| CA | Harvey Mudd College | IN | Purdue University | NC | University of North Carolina-Charlotte |
| CA | Pomona College | IN | Rose-Hulman Inst | NC | University of North Carolina-Pembroke |
| CA | San Diego City College | IN | Taylor University | ND | North Dakota State Univ |
| CA | San Diego State Univ | KS | Pittsburg State | ND | Univ of North Dakota |
| CA | San Francisco Art Institute | KS | University of Kansas | NE | Univ of Nebraska – Lincoln |
| CA | UC-Berkeley | KS | Wichita State University | NH | Dartmouth College |
| CA | UC-San Diego | KY | Eastern Kentucky University | NJ | College of New Jersey |
| CA | Univ of San Diego | KY | Univ of Kentucky | NJ | Princeton Univ |
| CA | Univ of Southern California | LA | Louisiana State Univ | NJ | Rowan University |
| CO | Colorado School of Mines | LA | Louisiana Tech Univ | NM | New Mexico State |
| CO | Colorado State Univ | MA | Harvard University | NM | New Mexico Tech |
| CO | US Air Force Academy | MA | Massachusetts Inst of Tech | NM | Univ of New Mexico |
| CO | Univ of Colorado-Boulder | MA | Smith College | NV | Univ of Nevada-Reno |
| CT | Fairfield University | MA | Tufts Univ | NY | Alfred University |
| CT | Wesleyan Univ | MA | U Massachusetts-Lowell | NY | Cornell University |
| CT | Yale University | MA | Wellesley College | NY | Fordham University |
| DC | George Washington Univ | MD | Johns Hopkins University | NY | Polytechnic University |
| FL | Broward Community College | MD | United States Naval Academy | NY | Rochester Inst of Technology |
| FL | Embry-Riddle Aeronautical Univ | MD | Univ of Maryland-College Pk | NY | State Univ of New York Buffalo |
| FL | Florida A&M Univ | ME | Univ of Southern Maine | NY | Syracuse Univ |
| FL | Florida Institute of Technology | MI | Hope College | NY | United States Military Academy |
| OH | Case Western Reserve Univ | SC | College of Charleston | TX | UT-Austin |

| | | | | | |
|---|---|---|---|---|---|
| OH | Ohio Northern Univ | SD | South Dakota School of Mines & Technology | TX | UT-Dallas |
| OH | Ohio State Univ | TN | Rhodes College | TX | UT-El Paso |
| OH | Univ of Cincinnati | TN | Tennessee State University | TX | UT-San Antonio |
| OH | Univ of Toledo | TN | Tennessee Technological University | UT | Brigham Young |
| OK | Oklahoma State University | TN | University of Tennessee | UT | Univ of Utah |
| OK | Univ of Oklahoma | TX | Austin Community College | UT | Utah State Univ |
| OK | Univ of Tulsa | TX | Collin County Community College | VA | Virginia Tech |
| OR | Oregon Inst of Technology | TX | El Paso Community College | VT | Norwich Univ |
| OR | Oregon State Univ | TX | Lamar Univ | VT | Univ of Vermont |
| OR | Portland State University | TX | Prairie View A & M Univ | WA | Seattle Central Community College |
| OR | Western Oregon University | TX | Rice Univ | WA | Seattle Univ |
| PA | Carnegie Mellon | TX | San Jacinto College-North | WA | Univ of Washington |
| PA | Drexel Univ | TX | S.F. Austin St Univ | WA | Washington State |
| PA | Penn State Univ | TX | Texas A&M Univ | WI | Carthage College |
| PA | University of Pittsburgh | TX | Texas Christian Univ | WI | Ripon College |
| PR | Univ of Puerto Rico-Mayaguez | TX | Texas State University | WI | Univ of Wisconsin-Madison |
| RI | Brown Univ | TX | Texas Southern University | WV | Bethany College |
| RI | Community College of Rhode Island | TX | Texas Tech | WV | Marshall Univ |
| RI | Univ of Rhode Island | TX | Univ of Houston | WV | West Virginia University |
| SC | Clemson University | TX | Univ of Houston-Clear Lake | WY | Univ of Wyoming |

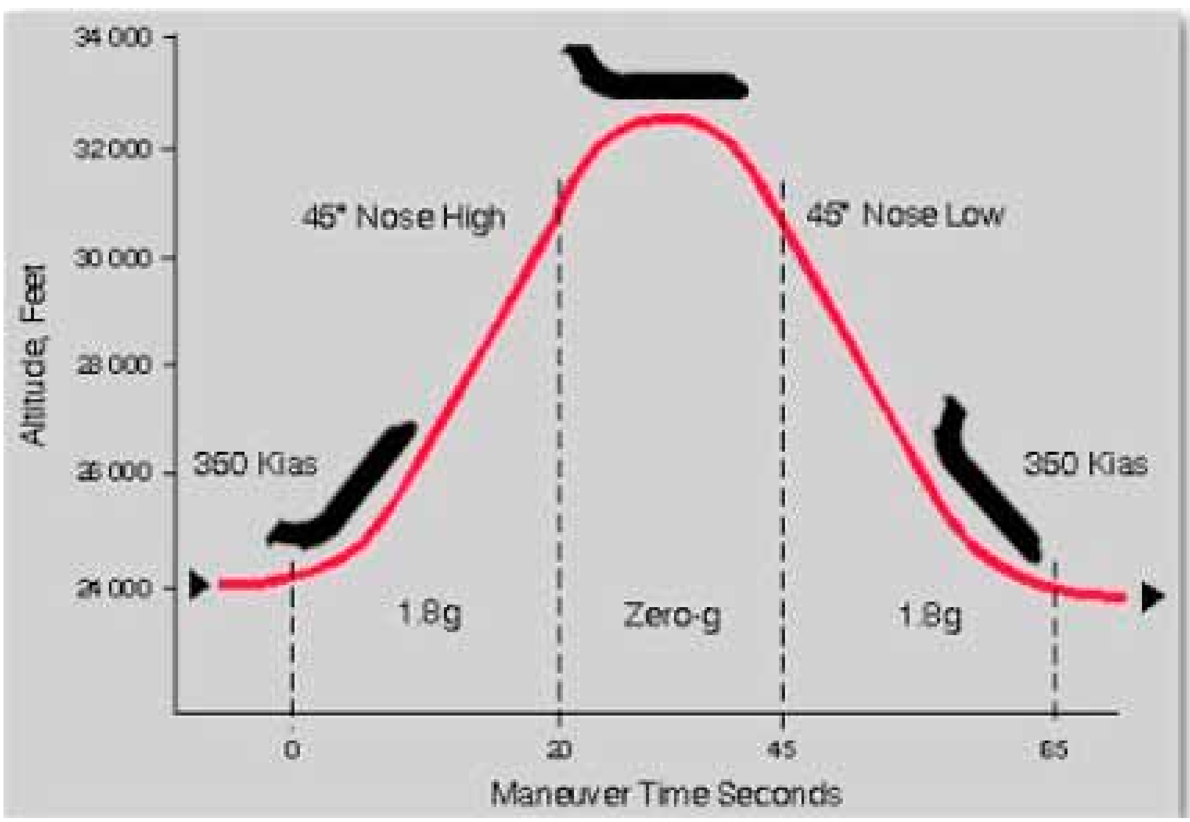
2010 participants are highlighted in blue


Flight Day photo of the Systems Engineering Educational Discovery Flight Week.

# Appendix 7 – About the Microgravity Aircraft

The NASA-JSC Reduced Gravity Research Program flies on a modified Boeing 727 aircraft.  The aircraft is crewed by a pilot, a copilot, a flight engineer, and two reduced gravity test directors. For the student campaign, a flight doctor, two video crew members and two photographers are also on board. Most test equipment is bolted to the floor using 20-inch tiedown grid attachment points.

The reduced gravity aircraft generally flies 30 parabolic maneuvers over the Gulf of Mexico. This parabolic pattern provides about 30 seconds of hypergravity (about 1.8G-2G) as the plane climbs to the top of the parabola. Once the plane starts to “nose over” the top of the parabola to descend toward Earth, the plane experiences about 18-25 seconds of microgravity (0G). At the very top and bottom of the parabola, flyers experience a mix of partial G’s between 0 and 1.8 (called “dirty air”).



# Appendix 8 – Program History

**Reduced Gravity Program Beginnings:** In 1995, Ellington Field's Aircraft Operations Chief, Bob Naughton, accompanied NASA's reduced gravity aircraft to Europe to fly the European Space Agency's student parabolic flight campaign. Mr. Naughton, impressed with the success of ESA's flights, discussed the idea of a US parabolic flight campaign with NASA Headquarters and Johnson Space Center managers. Headquarters Education Chief Frank Owens liked the idea, as did (then) Deputy JSC Director George Abbey. In the summer of 1995, Abbey and Owens (with the support of the Texas Space Grant) prototyped the first US student parabolic flights.

**1995** A pilot program was designed to provide a reduced gravity research opportunity for four teams of college seniors and graduate students from Texas' Rice and Texas A&M universities. The pilot program was called SURF (Students Understanding Reduced Gravity Flight).

**1996** The program was repeated during the summer of 1996, again with four teams from Texas institutions: Lamar University, Rice University, Texas A&M University and the University of Houston. In the fall of 1996, SURF was renamed "Reduced Gravity Student Flight Opportunities Program (RGSFOP)" and expanded to include universities nationwide.

**1997** Spring 1997 flights provided research opportunities for twenty-three teams from fifteen states. For the first time, journalists were permitted to fly as "team members."

**1998** The RGSFOP doubled program "slots" in 1998 to include forty-seven participating teams from thirty-seven institutions in twenty-four states.

**1999** A second yearly competition was born in 1999, which allowed for flights in both spring and summer. Forty-four teams from thirty-three institutions in twenty-one states participated during summer 1999.

**2000** RGEFP hosted 48 teams in March 2000. Because of KC-135 maintenance delays, 34 teams selected to participate in the Summer 2000 program were shifted into Spring 2001 program slots.

**2001** Forty-eight teams participated in the Spring 2001 RGSFOP. Thirty-three teams were those shifted from the Summer 2000 program; the remaining fifteen teams were selected during the Spring 2001 competition.

**2002** The Aerospace Academy (a division of San Jacinto College) accepted administrative responsibilities for the Reduced Gravity Student Flight Opportunity Program. The Microgravity University Office was born. A program coordinator and deputy coordinator, under the direction of Dr. Donn Sickorez, assisted the fifty-one teams who participated in the Spring and Summer flight weeks for the 2002 campaign.

**2003** A record number of seventy-two teams were chosen to participate. Among these were seventeen first-time institutions and eleven minority teams. In addition, the program experienced an increase in minority participation.

**2004** The RGSFOP extended offers to participate to sixty-nine student teams. Three NASA Explorer Schools and one Informal Education team were also invited to participate as part of a pilot program. Although the student program has been in existence in some form for nearly a decade, it is continuing to reach new audiences. This year, six new institutions and seven minority institutions were among the selected teams. This was also the last student group to experience reduced gravity on the KC-135.

**2005** The program moved to the C-9 aircraft. Modifications and issues with the aircraft caused delays and cancellations. In all, only ten teams and thirty-two students flew. Teams were rolled over to the 2006 program.

**2006** Flights returned to normal, as sixty-five teams are selected from 2005 and 2006 proposals. The first teams from Kansas, Pittsburg State and University of Kansas, fly their experiments. In addition, the first full group of museums and science centers are flown.

**2007** In addition to the typical zero gravity parabolas, the student program's first lunar gravity experiments are flown. Lamar University, Michigan Technological University, and University of Missouri-Rolla flew experiments for 30 parabolas at 1/6G. Experiments ranged from lunar dust removal to welding.

**2008** Two additional programs were added: Network of Educator Astronaut Teachers (NEAT) and the Systems Engineering Educational Discovery Program (SEED). Three states were also added to the participating states (Nebraska, Alaska, and Maine). The program changed its name to the Reduced Gravity Education Flight Program to reflect the teacher components.

**2009** The program moved to a contractor Boeing 727 aircraft. Through the special opportunities flight week, internal partnerships were explored as well as revisiting the policies of human-testing and the high school program.

**2010** Four additional partnerships were added: The NASA Explorer Schools (NES) Opportunity flight week brought additional teams representing NASA Science, Engineering, Mathematics and Aerospace Academy (SEMAA) and Motivating Undergraduates in Science and Technology (MUST). An additional flight week was developed in conjunction with NASA Teaching from Space (TFS) Office and National Science Teachers Association (NSTA). Also added were two flight teams from the U.S. Department of Energy (DOE) in conjunction with the Princeton Plasma Physics Laboratory (PPPL).

15

1995 - 2010

REDUCED GRAVITY
EDUCATION FLIGHT
PROGRAM

# Program Support

To successfully complete the flight season, it takes the effort and generous support of numerous groups and the Reduced Gravity Education Flight Program would like to take this opportunity to thank the following organizations and individuals.

### NASA Funding Sources:

Space Operations Mission Directorate
Exploration Science Mission Directorate
NASA Explorer Schools Program
JSC Teaching from Space Office
National Space Grant Consortium
Science, Engineering, Mathematics and Aerospace Academy (SEMAA)
Motivating Undergraduates in Science and Technology (MUST)
U.S. Department of Energy: Princeton Plasma Physics Laboratory

### Other Sources:

State Space Grant Consortium for supporting their flight teams
National Science Teachers Association (NSTA)

### Proposal Evaluation Support:

Undergraduate Technical Review Manager – John McQuillen (Glenn Research Center)
Undergraduate Technical Review Manager – Edward Jeffries (Marshall Space Flight Center)
Technical Reviewers from Glenn Research Center, Johnson Space Center and Marshall Space Flight Center
Safety Reviewers from Johnson Space Center – Dominic Del Rosso, Christopher Nelson and Fernando Zumbado
Education Outreach Reviewers from Johnson Space Center

## Program Support:

| **Ellington Field** | | **Mentors** | | |
|---|---|---|---|---|
| **Lead Test Director** | Dominic Del Rosso | Juan Agui - GRC | Christopher Johnson | Timothy Pelischek |
| **Test Director** | Terry Lee | John Bain | James Johnson | Curt Peternell |
| **Office Manager** | Rose Aquilina | Ernest Bell | Alex Kanelakos | Heidi Poppelreiter |
| **Engineer** | Kevin Krolczyk | Jonathan Braun | James Krzmarzick | Sarah Ruiz |
| **Engineer** | Noel Caasi | Tess Caswell | Kerry Lee | Amy Schellhase |
| | Aircraft Operations | Pedro Curiel | Thomas Leimkuehler | Rubik Sheth |
| | Engineering Department | Rebecca Cutri-Kohart | Jasmin Lindo | Samantha Snabes |
| | Safety Office | Mark Dub | Ben Longmier | Ashley Tarpley |
| **Human Test Support Group** | | Gregory Galloway – KSC | Laura Lucier | Evan Thomas |
| **Supervisor** | Mike Fox | Tamra George | Chip McCann | Fiona Turett |
| | Javier Roque | Jayleen Guttromson | Sally Nash | Paul Uranga |
| | Susan Crosbie | Jeremy Hart | Christopher Nelson | Aaron Weaver – GRC |
| | Flight Surgeons | David Hirsch - WSTF | Gregory Pace - ARC | Fernando Zumbado |
| | Staff Members | Edgar Hudson | Zarana Patel | Jennifer Zumbado |
| **Imagery Acquisition Group** | | Dan Isla – JPL | | |